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INVESTIGATION OF THE HUMAN FACTORS INVOLVED IN MINE DETECTION IN VARYING OPERATIONAL ENVIRONMENTS

Jeffery L. Maxey, et al

Human Resources Research Organization

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Investigations of the Human Factors Involved in Mine Detection in Varying Operational Environments

by

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HUMAN RESOURCES RESEARCH ORGANIZATION

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The Human Resources Research Organization (HumRRO) is a nonprofit corporation established in 1969 to conduct research in the field of training and education. It is a continuation of The George Washington University Human Resources Research Office. HumRRO's general purpose is to improve human performance, particularly in organizational settings, through behavioral and social science research, development, and consultation.

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SUMMARY

This report presents the results of research accomplished on the four research tasks currently comprising Project IDENTIFY, Identification of the Individual Differences Involved in Human Mine Detection. Specifically, the report discusses the research accomplished on *Task D,* Testing, Evaluation, and Validation of a Film Simulator for Human Mine Detection; on *Task E,* Identification and Assessment of the Human Mine Detection Factors in Built-Up Areas, on *Task F,* Identification and Assessment of the Human Mine Detection Factors Involved in Vehicular Operations; and on *Task G,* Identification of the Potential Characteristics, Aptitudes, and Acquired Skills Involved in Human Detection of Mines: Reanalysis and Extension of Concepts.

Prior research under Project IDENTIFY during Fiscal Year 1973 addressed the identification of the potential characteristics, aptitudes, and acquired skills involved in the human detection of mines (*Task A*), the validation of these characteristics, aptitudes, and acquired skills (*Task B*), and the identification of appropriate selection and training methods for human mine and boobytrap detection (*Task C*).

Task D: Use of Film Simulator in Mine Detection Training

The *Task D* research was conducted in three phases: (a) completion of a film detection test (which employed a film simulator) and paper-and-pencil and performance tests, measuring individual differences thought to be predictive of detection proficiency; (b) completion of field tests of detection proficiency (a mine and boobytrap test and a surface-laid munitions test); and (c) analysis of the results of the testing.

Sixty-four soldiers at Fort Benning, Georgia completed all phases of *Task D* testing. Half of these men completed film and predictor testing in the morning and the field testing in the afternoon; the remaining men reversed this procedure and completed field testing in the morning and film and predictor testing in the afternoon. During field testing, speed of movement during search was assessed, and effort expended during search was rated. Also, the numbers of true detections, false detections, misses, and activations (on the mine and boobytrap course) were counted. On the mine and boobytrap course, the detection clue and/or error of device placement was determined when a detection was made, and the search technique employed by the men was assessed. Finally, General Technical (GT) aptitude area test scores for the subjects were obtained from personnel records.

Analysis of the *Task D* data indicated that order of field testing and order of film/field testing did not affect detection proficiency, so correlations among film and field test scores were computed for the entire sample. The correlations between film and mine and boobytrap test proficiency, as well as between film and surface-laid munitions test proficiency, were significantly different from zero ($r = .33$ and $.31$ respectively), but the magnitude of these correlations was low.

These results replicated a previous finding of researchers at the Picatinny Arsenal, to the extent that statistically significant correlations were found between film and field detection performance, however, the correlation (.60) reported by the Picatinny study was higher than those found in the present research. Statistical tests showed that there was no significant difference between the correlation obtained in the Picatinny study and in the present study. This result was interpreted to indicate that the true value of the correlation between film and field detection performance was probably between .31 and .60.

Correlations were calculated between *Task D* detection proficiency and nine individual difference measures. Only two measures were found to be correlated with

proficiency: speed of movement during search and level of effort expended during search.

Data analyses addressing the human factors involved in the detection of devices on the *Task D* mine and boobytrap detection course were also conducted. False detections continued to represent a very small percentage of the total detections produced by the men. In contrast to earlier IDENTIFY results, detection rate was not related to the above-ground or below-ground location of devices for the *Task D* mine and boobytrap course; analysis suggested this was due to a change in the difficulty level of above-ground devices. However, average detection distance was found to vary as a function of device size.

Task D device detectability was found to be related to the off-center distance for the small, on-path devices, as well as for the large, off-path devices. In addition, detection rate varied as a function of terrain vegetation. Finally, grade of the detection course appeared to affect the detection rate.

Analysis of detection clues revealed that color and shape were important factors in the detection of devices. Analysis of errors of placement indicated that inadequate camouflage was also important for detection of devices. Analysis of the search procedures employed by the men indicated that an area search/footfall combination achieved the best results.

Task E: Mine Detection in Built-Up Areas

The *Task E* research was also conducted in three phases: (a) identification of individual difference variables and development of a proficiency test for studying human detection performance in a built-up area, (b) completion of tests and inventories designed to assess the individual difference variables and the criterion test by 100 military personnel stationed at Fort Benning, and (c) analysis of the results of the testing.

For *Task E*, subjects completed 11 paper-and-pencil and performance tests which provided information on 13 individual differences. In addition, GT test scores were obtained from the men's personnel records, while their racial background was assessed through direct observation. The men also completed a proficiency test of mine and boobytrap detection conducted in a simulated office and in a simulated home environment. During this test, speed of movement during search was assessed and effort expended during search was rated. Also, the numbers of true detections, false detections, misses, and activations were counted. When a true or false detection occurred, the clue used by the subject in making the detection was determined. Finally, the search technique employed by the subjects was assessed.

Devices employed during the *Task E* proficiency testing were found to consist of two groups: (a) those detected or missed, but seldom or never activated; and (b) those detected or activated, but seldom or never missed. It was found that detection rate for each category of devices appeared to depend on different variables. For Detected/Missed devices, rate was associated with the location of the devices, while for Detected/Activated devices, rate was associated with level of visibility.

False detections during the *Task E* proficiency testing represented only a very small percentage of the total detections. Further, they occurred in only one test environment, the office setting. It was concluded that further research would be required to determine whether this result was an experimental artifact or a true result.

A search technique for built-up area detection was identified from the techniques employed by the subjects. This consisted of (a) alternation of floor and furniture

searching; (b) searching all areas systematically; (c) searching on, in, and under furniture; and (d) using the sense of touch to supplement visual search. However, it was not possible to determine to what extent the components of these techniques are important to its success. Further research will be required to correct this shortcoming.

A multiple regression equation, involving the measures derived from the predictor test battery developed during the Fiscal Year 1973 IDENTIFY research, was developed to predict the men's percent total detection for the built-up area proficiency test. The total criterion variance accounted for was 74 percent. One predictor (the average of the evaluators' effort ratings) accounted for 70 percent of the predictable criterion variance. This result suggests that this predictor battery was not adequate for predicting criteria performance in built-up areas, since one measure accounted for so much of the predictable criterion variance.

A factor analysis of the individual difference and performance measures strongly suggested that detection performance in a built-up area is probably not predictable from knowledge of individual differences which are not performance oriented, that is, measures which are not associated with task performance.

Task F: Mine Detection Factors in Vehicular Operations

The *Task F* research was conducted in two phases: (a) completion of criterion tests of detection proficiency conducted in two separate operational environments (road and cross-country settings) under three separate vehicular conditions (detection from a jeep, an armored personnel carrier (APC), and a tank); and (b) analysis of the results of the testing.

Seventy-two soldiers completed all phases of *Task F* testing. First, they completed a road detection course while traveling at two vehicular speeds (5 and 15 miles per hour). Next, they completed consecutively two cross-country detection courses, usually traveling at speeds less than 5 miles per hour. On the first of these courses, the men had to cross a hasty minefield, while on the second they had to cross a deliberate minefield. Performance measures for the three courses were: the percent of devices detected, the number of false detections produced, and the level of effort put forth by the subjects during the detection task. In addition, for the road course the estimated distance to each detected device was obtained, while for the two field courses vehicle location was obtained when the forward edge of the minefield was detected, as well as when it was thought the vehicle was out of the minefield.

Analysis of the *Task F* data showed that as the detection situation changed from a road to a field environment, detection performance from the jeep dropped from a high level to a lower level, while detection performance from the tank rose from a low level to a higher level. Detection performance from an armored personnel carrier, on the other hand, showed no significant variation as a function of operational environment. These results indicate that type of operational environment and type of vehicle from which the detection task is performed significantly affect level of detection proficiency.

Analysis of the data collected on the road detection course showed that vehicular speed, type of vehicle, visibility of devices, and left-middle-right placement of devices are all factors that affect the performance of the detection task when completed from a moving vehicle on a road. Analysis of the data collected on the cross-country courses indicated that type of vehicle, size of device, left/right location of devices on the detection course, and observer-to-device range are factors influencing detection proficiency on these courses.

Task G: Potential Characteristics, Aptitudes, and Acquired Skills in Mine Detection

Finally, as a result of questions and issues raised concerning an earlier study of mine and boobytrap detection performance, *Task G* was initiated to reanalyze a portion of the data from that field experiment. Specifically, the reanalysis focused on a reliability analysis of the data from individual subjects, the construct validity of the individual measurements, and further explorations of underlying dimensions that might be related to field detection performance.

The first set of analyses conducted during *Task G* was directed toward the study of the reliability of the *Task B* data collected during Fiscal Year 1973. Reliability analyses consisted of investigating the extent to which the four different pairs of lanes used in *Task B's* Course No. I constituted parallel forms of the same test. It was important, in order that findings be generalizable, that all subjects be presented nearly the same detection task. These analyses suggested the strong likelihood that this was the case.

Substantial additional findings also emerged from the *Task G* analysis concerning the probable nature of the detection task itself. Clear circumstantial evidence was developed that the processes underlying detection of subsurface devices are not the same as those involved in the detection of above-surface devices. Further, reasonably conclusive evidence was developed that the paper-and-pencil predictor tests used in attempting to predict field detection performance simply are in a different dimension from that of the performance itself. It had been demonstrated earlier that situational measures were more effective in predicting detection performance. The *Task G* analyses strongly confirmed those reports, and showed that the situational measures alone are within the same dimension as the detection performance. These results were also supported by individual difference analysis performed during *Task D*, *Task E*, and *Task F*.

Based on these observations, suggestions were developed for the derivation of a new model that might more adequately account for field mine and boobytrap detection performance. The new model is essentially an information rate processing model. It was hypothesized that individual differences might arise from three different areas, given this as a basic model. The first consists of possible differences between individuals in the rate with which they can process individual bits of information. The second lies in the willingness of the individual to work for long periods of time at rates approximating his maximum rates. The third consists of possible "chunking" of stimulus elements, that is, processing stimulus elements in groups rather than individually. The literature on information processing supports each of these three possibilities.

20. (Continued)

environment (*Task D*), but also to gather it for a built-up area environment (*Task E*). In addition, it was designed to identify the human factors involved in vehicular operations, both along an established road and in a cross-country setting (*Task F*). This research also provided an opportunity to test and evaluate a film simulator developed by the Picatinny Arsenal as a tool for the selection and training of military personnel (*Task D*). Finally, it provided an opportunity to re-examine the data from the FY 73 HumRRO study (*Task G*) to investigate the reliability of the data from individual subjects, the construct validity of the individual measurements, and the underlying dimensions of field detection performance.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report summarizes findings from the four research tasks comprising Project IDENTIFY for FY 74. During FY 73 research into the identification of the individual differences involved in mine detection produced a body of human factors data relevant to the mine detection problem. A major purpose of the FY 74 research was to continue gathering and analyzing human factors data in the area of unaided mine detection. This research was designed not only to gather additional human factors data for an unpopulated field
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FOREWORD

This report presents the results of research conducted by the Human Resources Research Organization to investigate the human factors involved in mine detection in various operational environments. This research represents an outgrowth of work begun in Fiscal Year 1973 to identify the potential aptitudes, characteristics, and acquired skills involved in human detection of mines.

This research was funded under Contract DAAK02-73-C-0116 (P0001) Project No. 3A460050 which was awarded to HumRRO by the U.S. Army Mobility Equipment Research and Development Center (USAMERDC), Fort Belvoir, Virginia. The purpose of this research was to provide support for the USAMERDC Human Mine Detector Research Program by developing quantitative data for input to countermine system/subsystem analyses and identifying specific parameters that are likely to influence the process of mine detection as it is conducted in various operational environments.

The research was performed by Mr. Jeffery L. Maxey, Mr. Theocore R. Powers, Dr. T.O. Jacobs, and Mr. George J. Magner. It was conducted under the direction of Dr. Jacobs, Principal Investigator and Director, HumRRO Division No. 4, Fort Benning, Georgia. In addition, Mr. Thomas Berrisford and Mrs. Nancy Oliver assisted in the data reduction and analysis phases of the research.

Military support, consisting of 1LT Raymond Costner, 1LT John Grasso, PSG Lathaniel Henderson, SFC Cornell Smith, SSG Jon Lang, SGT James Arnold, SP5 Lonsworth Smith, SP5 James Tripp, SP4 Ennis Brooks, SP4 Doretha Heyward, SP4 Ronald Keen, SP4 Deborah Ridout, and PFC Susan Raker, was provided by the U.S. Army Infantry Human Research Unit, which is commanded by LTC Robert G. Matheson.

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Investigations of the Human Factors Involved in Mine Detection in Varying Operational Environments

INTRODUCTION

Since 1967, HumRRO Division No. 4 has conducted research on the problem of detecting mines and boobytraps. This work has focused on unaided detection by the individual soldier in unpopulated field areas. During Fiscal Year 1973, Project IDENTIFY investigated the individual differences involved in mine detection (*Tasks A* and *B*) and, as well, produced a body of human factors data relevant to the mine detection problem.[1]

A major purpose of the IDENTIFY research during Fiscal Year 1974 was to continue the gathering of human factors data in the area of unaided mine detection. This research was designed not only to gather additional human factors data for an unpopulated field environment (*Task D*), but also to gather it for a built-up area environment (*Task E*). In addition, it was designed to identify the human factors involved in mine detection during vehicular operations, both along an established road and in a cross-country setting (*Task F*).

Along with collecting further human factors data relevant to mine detection, this research provided an opportunity for testing and evaluating a film simulator developed by the Picatinny Arsenal at Dover, New Jersey, as a tool for the selection and training of military personnel (*Task D*). Also, it provided an opportunity to reexamine the data from the Fiscal Year 1973 HumRRO study to study the reliability of the data from individual subjects, the construct validity of the individual measurements, and the underlying dimensions of field detection performance (*Task G*).

The research was conducted in four stages. Since the film simulator was not available at the initiation of the Fiscal Year 1974 work, *Task E* was begun first and was performed between September 1973 and February 1974. *Task G* overlapped with *Task E* and was completed during December 1973 and January 1974. *Task D* overlapped both *Task E* and *Task G* and was conducted from January through March 1974. Finally, *Task F* was completed between April and June 1974. The method of accomplishment and the results of these tasks are presented in Chapters 1 through 4 of this report. Chapter 5 discusses these results, and Chapter 6 reports the conclusions derived from the analysis of this year's IDENTIFY work.

It is expected that the information provided by this report will be used to provide support for the Human Mine Detector Research Program of the U.S. Army Mobility Equipment Research and Development Center (USAMERDC) by furnishing:

(1) Quantitative data for input to countermine systems analysis studies.

(2) Information that can be used to develop tactical training and testing procedures for field and built-up area exercises involving the detection of mines and boobytraps by military personnel.

(3) Human factors data that indicate the variables influencing personnel in detection of mines in varying operational environments.

[1] Maxey, Jeffery L., Powers, Theodore R., Jacobs, T.O., and Magner, George J. *Identification of the Potential Characteristics, Aptitudes, and Acquired Skills Involved in Human Detection of Mines*, HumRRO Technical Report 73-18, August 1973.

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Chapter 1

TASK D: USE OF FILM SIMULATOR IN MINE DETECTION TRAINING

BACKGROUND

Since 1970, scientists at the Picatinny Arsenal have conducted research on the detection of small, colored devices dropped into natural field environments. At the request of USAMERDC, these scientists developed a prototype film simulator that illustrated a field problem using simulated surface-laid munitions.[1] The filmed course was 200 feet long and 8 to 10 feet wide; it contained 40 simulated munitions. Two basic kinds of devices were used: a long plain simulate and a short plain simulate. Each either was camouflaged by a covering of peat moss, grass, or leaves, or was uncamouflaged. The course was filmed by a 16mm movie camera held 6 to 7 feet above the course on a traveling camera rack. The rack was moved along and above the course at approximately 4 feet per second on 1/8-inch steel cables.

To evaluate the film simulator, 20 subjects first completed the detection course during daylight hours. After an interval of at least one week, they viewed the film simulator. The dependent variable assessed during course completion and film viewing was the percentage of devices detected. A correction for guessing (R-W/Σ) was used to take false detections into account. While all of the simulated munitions were detectable in the field course, only 35 were detectable during film viewing because of technical difficulties experienced when the film was shot.

The film was viewed using a projector that allowed the subjects to adjust the speed of the film. This provided them with a means of controlling the speed at which the filmed terrain passed in front of their eyes, allowing a simulated control on speed of walking.

The correlation between field and film detection proficiency was .60 ($df = 18$, $p < .01$). This significant correlation suggested that performance in a field situation is related to performance in a simulation of the field situation. However, there was a basic problem with the design of the evaluation. Since film detection was preceded by field detection, it was possible that learning in the field situation influenced film performance. The design, therefore, did not provide for unequivocally establishing whether film detection proficiency was predictive of field detection.

A preferred design would have been to have one group of subjects view the film first and then complete the field detection course, while another group completed the field detection course first and then viewed the film. With this design, any order effects would have been balanced. In addition, the magnitude of order effects could have been assessed. A major purpose of the current research effort was to use this design to re-evaluate the Picatinny film simulator concept, but extending the Picatinny work by using both surface-laid munitions and the mine and boobytrap devices used in previous HumRRO work.

In addition to validation of the film as a training aid, this research also offered the opportunity to extend earlier HumRRO work in this area.

[1] Bucklin, B. and Wilson, R. *Laboratory Simulation of a Field Problem in Visual Detection*, Technical Memorandum 2077, Picatinny Arsenal, Dover, N.J., June 1973.

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APPROACH TO THE PROBLEM

Design

The design for the film simulator validation was a 2 x 2 factorial design. The order in which film testing occurred (prior to field testing vs subsequent to field testing) and order of criterion testing (mine and boobytrap test first, surface-laid munitions test second vs mine and boobytrap second, surface-laid munitions test first) were the between-subjects variables.

Subjects

The subjects for the validation were 64 enlisted AIT graduates, stationed at Fort Benning, Georgia. All wore fatigues, boots, helmets, and a web belt with poncho and canteen. In addition, each carried an M16A1 rifle.

Equipment

A variable speed 16mm motion picture projector was used to present a prototype film simulation. A Rod and Frame Test apparatus was employed to measure field dependence/independence.

Paper-and-Pencil Test Materials

The Hidden Figures Test (Cf-1), the Embedded Figures Test (ETS Group Version), the Activities Inventory, and the AM Scale were completed to gather information about the relationship of these tests to field detection performance. Brief descriptions of these tests are given in Appendix A.[1] General Technical (GT) aptitude area test scores were obtained from the men's personnel records. Finally, the men's racial background was observed so that the influence of this variable could be assessed.

Film

The film employed in the *Task D* study was an improved version of the film assessed by Bucklin and Wilson. It was prepared at the Picatinny Arsenal during October 1973. The filmed terrain was the same as that in the Bucklin and Wilson film. The course was 200 feet long and 8 to 10 feet wide; it contained 29 simulated surface-laid munitions. Two kinds of simulates were used: a silver or olive-drab disc, and a long olive-drab cylinder. The discs were approximately 1 1/8 inches in diameter, and the cylinders were about 6 inches long. There was no attempt to camouflage either discs or cylinders. The course was filmed according to the procedure followed by Bucklin and Wilson. Markers were placed at varying intervals ($\bar{X}$ = 72.9 inches, SD = 5.2 inches) to divide the course into 26 sections.

Test Site for Criterion Testing

A test course for the validation of the film simulator was established in the Gill Range area on the Fort Benning Military Reservation. This area was selected because it contained the wooded terrain and open fields that might be encountered during a mid-intensity conflict in a temperate zone, the current emphasis area for U.S. Army training.

[1] This appendix is based on material in an interim report to USAMERDC, "Identification and Assessment of the Human Mine Detection Factors in Built-Up Areas," by Jeffery L. Maxey, Theodore R. Powers, and George J. Magner (HumRRO IR-D4-74-3), January 1974.

The test course for the mine and boobytrap proficiency test consisted of one lane approximately one-half mile (800 meters) long. It was located in varied terrain that required movement up and down hills, under trees, and through a limited amount of underbrush. Forty devices were emplaced on this course (see Figure 1). The mine and boobytrap situations employed for this course were those an infantryman might encounter in lightly wooded terrain. As indicated in Figure 1, some devices were designed to produce a small explosion if touched.

The test course for the surface-laid munitions proficiency test consisted of one 200-foot lane, located in an area covered with tall grasses. Twenty-nine devices—discs and cylinders like those employed in the film—were placed on this lane (see Figure 2). They were laid out in such a way that their positions approximated the positions of similar devices in the film.

Procedure

Two four-man groups were tested on each testing day, 11-15 and 19-22 February 1974. The first four-man group reported to HumRRO by 0830 hours on each test day. These four men were individually tested using the improved film simulator according to the procedures developed by Picatinny Arsenal.[1] After completion of the film test, the men were tested using the Rod and Frame apparatus. This testing was monitored by an IDENTIFY project staff member and was conducted by two research specialists from the U.S. Army Infantry Human Research Unit. After testing, the men had lunch and then reported to the field proficiency test area.

The second four-man group reported to the Gill Range test area by 0830 hours of each test day. On arrival at the field test area, the men were assigned an identification number and divided into two two-man groups. Men in Group I completed the mine and boobytrap detection course first, then the surface-laid munitions course. Men in Group II completed the surface-laid munitions course first, then the mine and boobytrap course.

Prior to the field testing, they participated in a short lecture-conference on detection of mines and boobytraps emplaced both above and below ground, reviewing the basic instruction on this topic presented during Basic Combat Training (BCT) and Advanced Individual Training (AIT). Next, they were given specific information about the devices and deployment techniques likely to be encountered on the two test courses. This information approximated the intelligence an infantryman might receive prior to an operation in an unfamiliar area. The men were also given instruction in the observation methods used by experienced mine and boobytrap observers, and were advised to use a systematic approach during testing, to insure coverage of critical areas. Next, they received instruction in the basic clues that indicate the presence of mines and boobytraps. Finally, they were shown examples of the devices they were likely to encounter during the proficiency testing.

The men were then told to assume that: (a) they were in a tactical situation acting as a point man for their small reconnaissance patrol, (b) their operations area was known to contain various types of mines and boobytraps, and (c) their mission was to visually locate these devices so a path could be cleared through the area. Subjects were told to move along until they thought they saw something that indicated the presence of a mine or boobytrap, and then to stop. Upon stopping, they were instructed to point to the location of the suspected device, state verbally the nature of the detection clue that indicated the presence of the device, and wait for the evaluator to tell them to begin moving again.

The men were allowed to bend at the waist to look at a suspected area while they were moving. Also, they were allowed to crouch down to look more closely and to brush

[1] Bucklin and Wilson, *op. cit.*

Sequence and Location of Devices on Mine and Boobytrap Test Course

Device No.	Type of Device	Off-Center[a] Distance	Grade[b]			Terrain[c]			Location
			Up	Level	Down	Open	Veg.	Restr.	
1	Schumine[d]	0		X				X	Ctr
2	Grenade	0	X					X	Ctr
3	M1A1[d]	0			X			X	Ctr
4	105mm	6 feet	X				X		R Side
5	M16[d]	0	X					X	Ctr
6	Grenade[d]	0	X					X	Ctr
7	Schumine[d]	0	X					X	Ctr
8	Claymore	5 feet	X				X		L Side
9	Grenade[d]	0	X					X	Ctr
10	M16[c]	0	X			X			Ctr
11	Grenade[d]	0	X					X	Ctr
12	M1A1[d]	0	X					X	Ctr
13	105mm	6 feet	X				X		L Side
14	M16[d]	0	X					X	Ctr
15	DH10	9 feet	X				X		R Side
16	Grenade[d]	0	X				X		Ctr
17	Schumine[d]	1 foot	X				X		L Ctr
18	Claymore	8 feet		X			X		L Side
19	M1A1[d]	0		X				X	Ctr
20	M16[d]	6 inches		X		X			Ctr
21	Grenade[d]	0			X			X	Ctr
22	M16[d]	1 foot			X	X			R Ctr
23	Claymore	4 feet		X			X		R Side
24	M1A1[d]	4 inches			X	X			L Ctr
25	105mm	4 feet			X		X		L Side
26	Grenade[d]	0			X			X	Ctr
27	Schumine[d]	0			X			X	Ctr
28	M16[d]	0			X		X		Ctr
29	DH10	8 feet			X		X		R Side
30	Grenade[d]	0			X			X	Ctr
31	M1A1[d]	18 inches			X		X		R Ctr
32	M16[d]	0			X			X	Ctr
33	105mm	3 feet			X	X			R Side
34	Schumine[d]	6 inches		X		X			L Ctr
35	Claymore	4 feet			X	X			R Side
36	Grenade[d]	0	X					X	Ctr
37	M16[d]	1 foot			X	X			L Ctr
38	Grenade[d]	0			X	X			Ctr
39	Schumine[d]	0			X			X	Ctr
40	M1A1[d]	6 feet			X	X			R Ctr

[a]Distance from path used by subjects.
[b]Moving uphill, level ground, moving downhill.
[c]Open (little vegetation), vegetation (some vegetation), restricted (vegetation closes in and limits width of path).
[d]Device rigged to produce small harmless explosion.

Figure 1

Plan for Surface-Laid Munitions Test Course

Markers	Left	Center	Right
	Location of Device		
26-27			LG
25-26			
24-25			
23-24			
22-23	RG		
21-22			LG
20-21	RG		LG
19-20		LG	
18-19	RS	RG	
17-18		RG	
16-17			RS
15-16	RG		
14-15		RG	RS
13-14			RG
12-13	RS		
11-12		LG	LG
10-11			RS
9-10	RS		
8-9		RG	
7-8		RS	
6-7			
5-6	LG	RS	LG
4-5			
3-4	LG	LG	
2-3	RS		
1-2		RS	RS

RS=Round Silver
RG=Round Green
LG=Long Green

Figure 2

away any material to confirm an identification. Since the emphasis during the testing was on visual detection, the men were not allowed to use sticks or rods to aid in detection.

After they received all instructions, they were taken to their appropriate starting points. The evaluators reviewed the testing instructions with each man, prepared his evaluation forms, and then commenced the testing.

As each subject moved from his starting point, his evaluator started a stopwatch, then followed the subject and observed him carefully. When a subject stopped to point to a suspected device, the evaluator stopped the watch and recorded the elapsed time. Next, the evaluator recorded the verbal report of the clue that the subject used for his detection. Finally, he recorded the estimated distance to the suspected device and indicated whether the subject's detection was an actual detection or a false detection. Evaluators did not indicate to the subjects whether a detection was an actual or a false detection.

When damage to a course occurred through the action of a subject, the evaluator repaired the damage so the course was restored to its original condition and ready for another subject.

Upon completion of a course, the evaluator returned the subject to an assembly point and recorded the search technique used by the subject. He also rated the degree of detection effort expended by the subject on a five-point scale (unsatisfactory to outstanding). Evaluators were told to make these ratings on the degree of effort exhibited by the subject rather than on detection success. Finally, the evaluator collected all the subject's evaluation materials, turned these in, and prepared to test another subject.

These procedures were followed for both the morning and afternoon hours. Thus, on each day of testing, half the subjects completed the field testing in the morning while the other half completed the film and predictor tests. During the afternoon this procedure was reversed.

RESULTS

Evaluation of the Film Simulator

To examine the validity of the film simulator for both a surface-laid munition and a mine and boobytrap detection situation, analyses were conducted on the data collected during the film and field testing. The primary data for the analyses were the percentage of devices detected during testing. These scores were not corrected for guessing, since the average number of false detections produced per subject in the testing was generally small (see Table I).

Table I

False Detections Produced During Testing

Test	Percent of Subjects Producing False Detections	Total Number of False Detections	Average Number of False Detections by Subjects Who Made False Detections
Film Testing	67.2	137	3.2
Field Testing			
Mine and Boobytrap Course	1.6	1	1.0
Surface-Laid Munitions Course	3.1	2	1.0

The first analyses performed were a series of two-way analyses of variance of the film and field test scores. Tables II, III, and IV present the results of these analyses. In each case, the main effects and the interaction were not significant. Table V presents the mean and standard deviation for each treatment condition and the main effects for these analyses.

These results clearly indicate that (a) subjects completing the film test prior to field testing did not perform at a significantly higher level on either the surface-laid munitions or mine and boobytrap tests than did subjects completing these field tests without prior film experience, and (b) subjects completing the field tests prior to film testing did not perform at a significantly higher level on the film test than did subjects completing the film test without prior field experience.

Table II

Analysis of Variance of Film Test Scores

Source of Variance	*df*	MS	*F*
Order of Film/Field Testing (OFF)	1	264.06	1.52
Order of Field Testing (OFT)	1	189.06	1.09
OFF X OFT	1	3.07	< 1
Error	60	174.12	

Table III

Analysis of Variance of Mine and Boobytrap Test Scores

Source of Variance	*df*	MS	*F*
Order of Film/Field Testing (OFF)	1	9.77	< 1
Order of Field Testing (OFT)	1	9.77	< 1
OFF X OFT	1	284.76	1.47
Error	60	194.25	

Table IV

Analysis of Variance of Surface-Laid Munitions Test Scores

Source of Variance	*df*	MS	*F*
Order of Film/Field Testing (OFF)	1	22.56	< 1
Order of Field Testing (OFT)	1	312.56	3.95
OFF X OFT	1	13.57	< 1
Error	60	79.05	

Table V

Mean and Standard Deviation for Each Treatment Condition and Main Effect for Film and Field Test Scores

(Percent)

Test Score	Mine and Boobytrap Test Completed First		Surface-Laid Munition Test Completed First		Combined Groups	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Film Test						
Film Test 1st - Field Tests 2nd	41.4	16.0	44.4	12.9	12.9	14.4
Field Tests 1st - Film Test 2nd	45.0	14.3	48.9	8.5	46.9	11.7
All groups					44.9	13.2
Mine and Boobytrap Test						
Film Test 1st - Field Tests 2nd	71.9	9.9	68.5	18.8	70.2	14.9
Field Tests 1st - Film Test 2nd	66.9	15.4	71.9	9.5	69.4	12.8
All groups					69.8	13.8
Surface-Laid Munitions Test						
Film Test 1st - Field Tests 2nd	90.2	10.4	92.8	8.8	91.5	9.6
Field Tests 1st - Film Test 2nd	89.8	10.0	95.6	5.4	92.7	8.4
All groups					92.1	9.0

Since analysis of variance indicated that the two orders of film and field testing did not have a differential effect on either film or field test scores, correlations among these scores were computed for the entire sample (Table VI). All of these correlations were significantly different from zero, but the magnitudes of the correlations were all relatively low. These results indicate that (a) film test performance was statistically related to field test performance for both similar and dissimilar field environments, but only at a relatively low level in each case; and (b) only a small amount of common variance (25%) was shared between the two field tests.

Table VI

Correlation[a] Between Film and Field Test Scores for the Total Sample

(N = 64)

Test	Film Test	Surface-Laid Munitions Course	Mine and Boobytrap Course
Film Test	--		
Field Test–Surface Laid Munitions Course	.31*	--	
Field Test–Mine and Boobytrap Course	.33**	.50**	--

[a]** indicates statistical significance, $p < .01$. *, $p < .05$

These results replicate Bucklin and Wilson's finding, that film performance was related to field detection performance only to the extent that in both cases a significant film/field performance correlation was found. However, in their work the magnitude of this correlation was .60 ($p < .01$), while in the present case it was only .31 ($p < .05$) for a surface-laid munitions course, and .33 ($p < .01$) for a mine and boobytrap course.

Several factors may have contributed to a lower correlation for the present research: different subject populations, different films, and different test environments. A test to determine whether the correlations obtained in the present research were significantly different from Bucklin and Wilson's correlation showed that in both cases the differences were not significant (see Table VII). This result suggests that the true value of the film/field performance correlation lies between .31 and .60. Further research would be needed to establish the value more precisely.

Table VII

Comparison of *Task D* and Picatinny Arsenal Correlations for Film/Field Test Performance

Correlation	*r*	*N*	*Z*	*p*
Picatinny Arsenal Correlations Between Film and Surface-Laid Munitions Test	.60	20	–	–
Task D Correlation Between Film and Surface-Laid Munitions Test Performance	.31	64	1.38	NS
Task D Correlation Between Film and Mine and Boobytrap Test Performance	.33	64	1.30	NS

Individual Difference Data Analysis

Table VIII presents the correlations between the nine individual difference variables assessed during testing and detection performance (percent detections) for the film test, the surface-laid munitions test, and the mine and boobytrap detection test. Only two differences were found to be significantly correlated with detection performance, and only for the two field tests: search speed and course length, that is, Time to Complete Test and Effort Expended During Search.

These results parallel those of the previous IDENTIFY research. Only individual differences directly related to the task situation have been consistently found to correlate significantly with detection performance. This reinforces the conclusion that the skills measured by paper-and-pencil tests are probably on a different dimension than the skills employed during the performance of a detection task in a field environment. It follows that situational requirements are probably the major factors influencing the level of detection performance attained by a given individual.

Human Factors Data Analysis

To investigate further the human factors involved in the detection of mines and boobytraps, the data collected during the mine and boobytrap test were analyzed to identify factors influencing detection performance. A total of 1788 detections were made during the mine and boobytrap test. Of these, only one was a false detection. As in

Table VIII

Correlations[a] Between Film and Field Detection Performance and The Individual Differences Assessed During Testing
(N = 64)

Individual Difference	Film Detection	Surface-Laid Munitions Detection	Mine and Boobytrap Detection
Rod and Frame Test Score	-.14	-.06	.00
Hidden Figures Test Score	.08	.05	.24
Embedded Figures Test Score	.23	.03	.14
Activities Participation Index	.13	-.01	.08
AM Scale Score	.02	-.21	.17
GT Test Score	.16	.11	.03
Racial Background	.10	-.04	-.11
Time to Complete Test	.16	.40**	.54**
Effort Expended During Search	b	.74**	.46**

[a]** indicates statistical significance, $p < .01$.
[b]Effort ratings were not made by the test administrator for the film testing.

previous IDENTIFY research, false detections continued to represent a very small percentage of the total detections.

The detection rate for this test was 69.8 percent, while the miss rate was 24.6 percent. The activation rate was 5.6 percent. The 40 devices employed in this test would be separated into two basic categories: above-ground and below-ground devices. Above-ground devices included 2 DH10s (simulated Russian Claymore type mines); 10 hand grenade tripwire boobytraps; 4 105mm rounds and 4 M18A1 antipersonnel mines (APM). Below-ground devices included 6 Schumines; 6 M1A1 activators attached to simulated TNT blocks; and 8 M16 antipersonnel mines.

Inspection of Table IX shows that detection rate did not appear to vary as a function of a device's location above ground or below ground. For both types of devices

Table IX

Detection, Miss, and Activation Rates for Above-Ground and Below-Ground Devices
(Percent)

Device	Detection Rate	Miss Rate	Activation Rate
Above-Ground			
DH10 (Simulated Russian Claymore Type Mine)	83.6	16.4	0.0
Hand Grenade Tripwire Boobytrap	75.0	6.1	18.9
105mm Round	58.6	41.4	0.0
M18A1 Antipersonnel Mine	48.8	51.2	0.0
Below-Ground			
Schumine	79.7	18.2	2.1
M16 Antipersonnel Mine	75.0	23.0	2.8
M1A1 Activators Attached to Simulated TNT Blocks	61.2	37.5	1.3

there was a spread in the detection rates from low to high within approximately the same limits. This was also true for the miss rate.

Only one above-ground device (hand grenade tripwire boobytrap) was capable of activation. As a consequence, a comparison between above-ground and below-ground devices for the activation rate is somewhat misleading. However, it can be noted that the activation rate was substantially higher for the hand grenade tripwire boobytraps, which intersected the subjects' entire path, than for the three below-ground devices, which intersected the path only at their location.

The lack of a relationship between detection rate and a device's above/below ground location was in contrast to the results of the *Task B* research. Comparison of the detection rates for the present research and the *Task B* research (see Table X) showed that the above-ground devices for *Task D* were detected at a somewhat lower rate than the above-ground devices for *Task B*. On the other hand, the below-ground devices for *Task D* were generally detected at a higher rate than the below-ground devices for *Task B*.

Table X

Comparison of the *Task B* and *Task D* Detection Rates for Common Above-Ground and Below-Ground Devices

Device	*Task B* Percent Detected	*Task D* Percent Detected
Above-Ground		
DH10 (Simulated Russian Claymore Type Mine)	88.9	83.6
Hand Grenade Tripwire Boobytrap	77.5	75.0
105mm Round	68.8	58.6
M18A1 Antipersonnel Mine	67.1	48.8
Below-Ground		
Schumine	52.9	79.7
M16 Antipersonnel Mine	46.9	75.0

This result may have been due to an attempt to make above-ground devices more difficult to detect. In *Task B* it was observed that above-ground devices were generally easier to find than below-ground devices. For *Task D* it was decided an attempt would be made to reduce the ease of detection for these devices.

The results indicate that the attempt was successful. However, even though no attempt was made to change the difficulty of below-ground devices, the detectability of these increased. This suggests that the increased difficulty of detecting above-ground devices may have resulted in *Task D* subjects orienting more toward the ground than did *Task B* subjects. The result of such a reorientation would be a higher detection rate for below-ground devices. The implication is clear: The detectability of above-ground and below-ground devices may be affected by changes in the difficulty level of either type of device.

Table XI presents the average estimated distance at which each type was detected. From inspection of this table, it is clear that device size was related to the distance at which detection occurred. The small devices (hand grenade tripwire boobytraps, Schumines, M16 antipersonnel mines, and M1A1 activators) were detected at shorter average distances than were the larger devices (simulated Russian DH10s, 105mm rounds, and M18A1 antipersonnel mines). This result replicates the *Task B* finding that device detectability was related to device size.

Table XI

Average Estimated Distance at Which Each Type of Device Was Detected

Device	Relative Size[a]	Detection Distance (feet)	
		$\overline{X}$	SD
DH10 (Simulated Russian Claymore Type Mine)	L	19.4	9.4
105mm Round	L	15.0	11.1
M18A1 Antipersonnel Mine	M	13.8	11.1
M16 Antipersonnel Mine	S	2.3	1.7
Hand Grenade Tripwire Boobytrap	S	2.1	2.6
Schumine	S	2.1	1.9
M1A1 Activators Attached to Simulated TNT Blocks	S	1.8	4.1

[a]L = Large; M = Medium; S = Small.

To further examine the effect of environmental conditions on detectability, devices were classified in three ways: (a) by how far off the center of the subjects' path they were located, (b) by the type of terrain in which they were located, and (c) by the type of grade on which they were located. The results of these classifications are presented in Tables XII, XIII, and XIV.

Detection rate for devices located on the path along which the men traveled appeared to decrease as the off-center distance of devices increased (see Table XII). All of these devices were small-sized. This finding probably reflects the fact that as a small item is placed farther from the center of a path, it is more likely to appear in an individual's peripheral visual field, where vision is least accurate. Under these conditions, it would be expected that the probability of detection would decrease.

Average detection distance did not appear to vary with increased off-center distance. For all devices on the path (excluding hand grenade tripwire boobytraps) the activation rate dropped as the off-center distance increased. This result reflects the fact that as the on-path/off-center distance is increased, the probability of an undetected item being contacted and activated will decrease for individuals traveling in a line of advance which avoids the edges of the path.

For devices located off the path along which subjects traveled, detection rate and the average detection distance appeared to increase with increased off-center distance. This result suggests that size was the controlling factor in this case. For devices 4 to 5 feet off-center, three of the four were medium-sized, while of those 6 to 9 feet off-center, five of the six were large-sized. This result simply reflects the previous observation that larger devices tend to be detected at a higher rate, and at a longer distance, than smaller devices.

Detection rate also appeared to be related to the type of terrain in which the devices appeared (see Table XIII). For both below-ground and above-ground devices, detection rates appeared to increase as the terrain changed from little or some vegetation, to heavy vegetation. Probably this result reflects the fact that as vegetation on the terrain increased, the subjects became more cautious, sensing this was a danger area. As a consequence, a more thorough search could be accomplished in a given amount of time. This would, of course, result in a higher detection rate.

Table XII

Detection, Miss, and Activation Rates and Average Detection Distance for Devices as a Function of Their Off-Center Distance

Off-Center Distance (feet)	Type of Device	Size[a]	Location	N	Detection Rate (%)	Miss Rate (%)	Activation Rate (%)	Detection Distance (feet)	
								$\bar{X}$	SD
0	M1A1,M16,Schumine	S	On-Path	12	83.2	14.5	2.3	2.1	2.8
0	Grenade Tripwire	S	On-Path	10	75.0	6.1	18.9	2.1	2.6
0.33 - 0.28	M1A1,M16,Schumine	S	On-Path	4	64.4	33.6	2.0	2.0	1.3
1.00 - 1.50	M1A1,M16,Schumine	S	On-Path	4	47.3	52.7	0.0	2.1	1.5
4.00 - 5.00	M18A1,105mm Round	M	Off-Path	4	46.9	53.1	0.0	14.1	12.0
6.00 - 9.00	M18A1,DH10,105mm Round	L	Off-Path	6	68.2	31.8	0.0	16.6	10.3

[a] S = Small; M = Medium, L = Large.

Table XIII

Detection, Miss, and Activation Rates and Average Detection Distance as a Function of Type of Terrain in Which Devices Were Located

Type of Terrain	N	Type of Device	Detection Rate (%)	Miss Rate (%)	Activation Rate (%)	Detection Distance (feet)	
						$\bar{X}$	SD
Little or Some Vegetation	10	Below-Ground	61.2	37.5	1.3	2.0	1.3
	12	Above-Ground	65.0	33.6	1.4	12.7	11.2
Restricted	10	Below-Ground	83.3	14.4	2.3	2.2	3.2
	8	Above-Ground	70.9	7.6	21.5	1.9	1.9

Table XIV

Detection, Miss, and Activation Rates and Average Detection Distance as a Function of the Grade of the Ground on Which Devices Were Located

Grade	N	Detection Rate (%)	Miss Rate (%)	Activation Rate (%)	Detection Distance (feet)	
					$\overline{X}$	SD
Up	16	74.0	17.5	8.5	5.6	9.2
Level	6	74.0	25.3	.7	5.1	6.6
Down	18	64.7	30.6	4.7	4.4	6.8

For below-ground devices the average detection distance did not change, while for above-ground devices it dropped substantially as the amount of vegetation increased. Since below-ground devices were all on the subjects' path, it would be expected that the average detection distance would not change for these devices. However, for above-ground devices it would be expected that the average detection distance would drop, since the terrain background would be more complex, and, as a consequence, long-distance discriminations of the devices from the background would be more difficult.

Finally, detection rate appeared to be related to the kind of grade subjects encountered as they moved along the path of the test course (see Table XIV). For an upgrade and level grade, average detection rate was about the same. For a downgrade, the rate dropped. Average detection distance, however, showed little variation with grade.

This result is probably due to two factors: ground/eye distance, and fatigue. On an incline or on level ground, an individual's eye is closer to the ground than when he is on a decline. As a consequence, it could be expected that devices would be harder to detect on a decline. Also, the upgrade and level parts of the course were completed prior to the downgrade part of the course. As a consequence, by the time the downgrade was reached, the men may have been sufficiently fatigued so that their detection performance was adversely affected. If so, this would account for part of the above observed decrement from the upgrade and level grades to the downgrade.

Table XV presents the percentage of times each of seven detection clues aided in the detection of each type of device employed in the mine and boobytrap test. Overall, color and shape of the device were the dominant clues. However, the relative importance of the different clues differed for the different devices. Color was the dominant clue for the Schumines, M16s, M18A1s, and the hand grenade tripwires. For the DH10s and the 105mm rounds, however, shape was the dominant clue. For M1A1/TNT blocks, both color and shape were major clues. These results parallel those of Jacobs[1] which indicated that color was a dominant clue for Schumines, M16s, M18A1s, and M25s, while shape was dominant for the 105mm rounds and DH10s. Taken together, these separate sets of results suggest that at least two separate kinds of perceptual processes operated during the mine and boobytrap detection test.

Table XVI presents the percentage of times each of eight placement errors aided in the detection of each type of device used in the mine and boobytrap detection test.

[1] Interim report to USAMERDC, "Identification of the Potential Characteristics, Aptitudes, and Acquired Skills involved in Human Detection of Mines: Reanalysis and Extension of Concepts," by T.O. Jacobs (HumRRO IR-D4-74-5), January 1974.

Table XV

Percent of Times Each of Seven Detection Clues Aided in the Detection of Each Type of Device in Mine and Boobytrap Test

(Percent)

Detection Clue	Type of Device							
	DH10 (N=118)	Granade Tripwire (N=62)	105mm Round (N=179)	M18A1 AP Mine (N=124)	Schumine (N=314)	M16 AP Mine (N=157)	M1A1&TNT Block (N=157)	All (N=1111)
Device Color Variations	22.9	77.4	35.5	53.2	66.9	60.5	44.6	51.8
Device Size Variations	18.6		15.1	6.4	2.2	2.6	.6	6.2
Device Shape Variations	55.1	3.2	50.3	37.1	16.6	15.9	44.6	31.5
Device Texture Variations		11.3			4.8	1.3	.6	2.3
Surrounding Camouflage Variations		4.8	.6	1.6	7.3	18.8	9.6	6.9
Surrounding Vegetation Variations		3.2	.6	.8	1.9	1.3		1.1
Surrounding Soil Variations	4.0				.3			<1

Table XVI

Percent of Times Each of Eight Placement Errors Aided in the Detection of Each Type of Device in Mine and Boobytrap Test

(Percent)

Placement Error	Type of Device							
	DH10 (N=18)	Grenade Tripwire (N=433)	105mm Round (N=17)	M18A1 AP Mine (N=29)	Schumine (N=55)	M16 AP Mine (N=306)	M1A1&TNT Block (N=116)	All (N=973)
Inadequate Camouflage	88.3	1.6	41.2	51.7	69.1	31.5	44.0	23.5
Failure to Renew Camouflage	5.6		11.8		1.8	.7	1.7	.8
Continued Use of Same Technique				10.3				.3
Disturbed Soil					14.5	.3	1.7	1.1
Disturbed Vegetation	5.6		11.8		3.6			.5
Mine/Boobytrap Exposed		3.7	1.8	27.6	6.0	2.0	3.4	4.0
Exposed Triggering Device		91.7		3.4	3.6	64.6	39.7	66.1
Anticipated by Tactical Conditions	5.6	3.0	23.5	6.9	1.8	1.0	9.5	3.6

Overall, exposed triggering devices and inadequate camouflage were the primary placement errors that aided in the detection of devices. For the hand grenade tripwire boobytraps and the M16s, an exposed triggering device was the primary aid, while for the remaining devices, inadequate camouflage was the primary aid. Since an exposed triggering device may represent an extreme example of inadequate camouflage, these results imply that failure to properly camouflage devices is a sufficient condition for the detection of devices.

Table XVII summarizes the search procedures employed by the subjects as they completed the mine and boobytrap detection test. An F test revealed that the differences among the number detected for different search techniques were significant ($F = 10.35$, $dfs = 2, 61$, $p < .01$). A multiple comparison test revealed that the area search and footfall search combination was associated with a significantly larger number of detections compared to the other techniques. The extent to which the subjects looked up and out while they walked did not appear to be associated with the subjects' number of detections. Finally, the gait the men employed while searching (either a steady walk or a periodic pause) did not appear to be associated with the number of detections. Tests of significance supported these observations. In both cases F tests produced nonsignificant results (see Table XVII). These results suggest that a combination of area search and footfall is a superior search technique when compared to either area search or footfall search. Further, they suggest for the present study that searching out and up and subject's gait did not influence detection performance.

Table XVII

Search Procedures Employed by Subjects

Procedure	N	Number Detected $\bar{X}$	Number Detected SD
Technique			
Area Search or Primarily Area Search	2	19.0	9.9
Area Search and Footfall Combination	27	30.8	3.8
Footfall or Primarily Footfall	35	26.2	5.3
$F = 10.35; df = 2,61; p < .01$			
Extent to Which Subjects Searched Out and Up While Walking			
Never	12	29.5	5.3
A Little	41	27.7	5.6
A Lot	11	27.1	5.8
$F = < 1; df = 2,61$; NS			
Gait Subjects Employed While Searching			
Walked Steadily	53	28.2	5.6
Paused Periodically to Look	11	26.6	5.0
$F = < 1; df = 1,62$; NS			

Chapter 2

TASK E: MINE DETECTION II. BUILT-UP AREAS

BACKGROUND

Substantial research has been conducted in the last few years to discover the human factors involved in the detection of mines and boobytraps in field situations.[1,2,3] However, no known research has been performed to discover the human factors involved in the detection of these devices in built-up areas. Therefore, a major purpose of the *Task E* research was to investigate the contribution of both individual difference and situational factors to the detection process in a built-up area.

One product of the IDENTIFY research for FY 73 was a test battery for selecting military personnel who were likely to be proficient detectors of mines and boobytraps in a field environment. In order to further evaluate the generality of the predictor measures in this battery, a decision was made to collect data on them during the *Task E* research. This involved the completion of tests measuring binocular visual acuity, level of dogmatism (closed mindedness), and level of activities participation; the determination of the number of years of civilian education completed; the determination of the means by which high school had been completed (if at all); the measurement of the speed at which a proficiency test of detection was completed; and an evaluator's rating of the level of effort expended during the completion of this test by the subject.

In addition to measuring binocular visual acuity, it was suggested during a meeting with a consultant (Dr. W.W. Ronan) from the Georgia Institute of Technology, Department of Psychology, that visual disparity might be related to detection performance in a built-up area. Visual disparity is measured by first measuring visual acuity in each eye and then taking the absolute difference of these measures. To investigate this possibility, the Visual Acuity Test procedure was modified so measures of visual acuity in the left and right eyes could also be obtained.

During the meeting with the consultant it was also suggested that some measure of an individual's color vision be obtained. To accomplish this, a copy of the Army Color Perception Test was obtained from the Optometry Section of the Fort Benning Medical Department Activity. Scores from the completion of this test provided a measure of an individual's red-green color deficiency (if this was present).

In addition, several other individual difference measures were identified for assessment. These included three measures of field-dependence/independence (Hidden Figures Test, Embedded Figures Test, and Rod and Frame Test), a measure of the effort expended during search made by the subject, a measure of general ability, three measures

[1] Bucklin, B.L. *Field Dependence and Visual Detection Ability*. Technical Report 4137, Picatinny Arsenal, Dover, New Jersey, May 1971.

[2] Maxey, Jeffery L. and Magner, George J. *A Study of Factors Affecting Mine and Boobytrap Detection: Subject Variables and Operational Considerations*. HumRRO Technical Report 73-12, June 1973.

[3] Maxey, *et al., op. cit.*, August 1973.

of motivation (achievement motivation background, task persistence, and task orientation), and a measure of subjects' racial background.

In summary, 15 individual differences (see Table XVIII) were identified by the project staff for assessment during the completion of the *Task E* research. Seven of these differences (dogmatism, activities participation, civilian education, securement of high school diploma, task orientation, achievement motivation, and persistence) were amenable to assessment through paper-and-pencil testing. Three of the differences (visual acuity, acuity disparity, and red-green color deficiency) were amenable to measurement through performance testing. One difference (field dependence/independence) was amenable to measurement through both paper-and-pencil testing and performance testing. Measures of two differences (speed of movement and effort expended during search) were obtained as by-products of proficiency testing, while one difference (racial background) was obtained through direct observation of the subject. Finally, the last difference (general aptitude) was obtained from the subjects' personnel records.

Table XVIII

Individual Differences Assessed During *Task E* Testing

	Individual Difference	How Measured—Paper-and-Pencil Test
1.	Level of Dogmatism	IDENTIFY Opinion Questionnaire
2.	Level of Activities Participation	Activities Inventory—Part I
3.	Years of Civilian Education Completed	IDENTIFY Information Form
4.	Means by Which a High School Diploma Was Earned	IDENTIFY Information Form
5.	Task Orientation	Task Orientation Inventory
6.	Achievement Motivation	AM Scale
7.	Persistence	Hand Skills Test
8.	Field Dependence/Independence	Hidden Figures Test (Cf-1) Embedded Figures Test (ETS Grp. Version) Rod and Frame Test
9.	General Aptitude	GT Score from personnel records
	Individual Difference	**How Measured**
10.	Binocular Visual Acuity	Visual Acuity Test
11.	Acuity Disparity	Visual Acuity Test
12.	Level of Red-Green Color Deficiency	Army Color Perception Test: By-Product of criterion testing
13.	Speed of Movement During Search	Search time divided by distance traveled
14.	Effort Expended During Search	Evaluator rating of effort Subject rating of effort
15.	Racial Background	Direct observation

APPROACH TO THE PROBLEM

The identification of individual differences and situational factors related to detection proficiency in a built-up area was accomplished by collecting relevant individual difference data from military personnel and by having them complete a criterion test of detection proficiency in two environments: a simulated office and a simulated home.

Individual Difference Data Collection

The individual differences listed in Table XVIII were assessed (with the exception of Speed of Movement and Level of Effort During Search) outside of the criterion test situation. This assessment involved the collection of the information indicated in Table XVIII.[1]

Implementation of Testing

The paper-and-pencil tests and the performance tests were organized into a test battery requiring approximately 1.5 hours to complete. They were administered to 100 male enlisted personnel who were AIT graduates, stationed at Fort Benning, Georgia. All except one were combat naive. The subjects were members of the 36th Engineer Group, made available during the period 3 December through 14 December 1973. These subjects also completed a proficiency test developed to assess their ability to detect mines and boobytraps employed in a built-up area. During this test, speed of movement and level of effort expended during search were assessed. Also, the search technique employed during the test was assessed.

The subjects were tested in 10-man groups. Subjects reported to the U.S. Army Infantry Human Research Unit at approximately 0800 hours on each day of testing. At that time they were split into two subgroups of five men each. The first s[illegible] began completion of the criterion test, while the second subgroup began completion of the paper-and-pencil and performance test battery. All testing was completed between 0800 and 1200 hours of each testing day.

The paper-and-pencil and performance test battery was administered by a HumRRO research scientist with the assistance of a Human Research Unit specialist and a HumRRO clerk. Generally the subjects completed self-administered questionnaires and inventories first, then individually administered tests. Finally, in a group testing situation, they completed tests with time limits.

The proficiency test was administered in two wooden buildings in the Human Research Unit area. A one-story building was modified to simulate a civilian office environment. A two-story building was modified to simulate a civilian residence. The bottom floor was set up to look like civilian living quarters; the top floor was set up to look like civilian sleeping quarters.

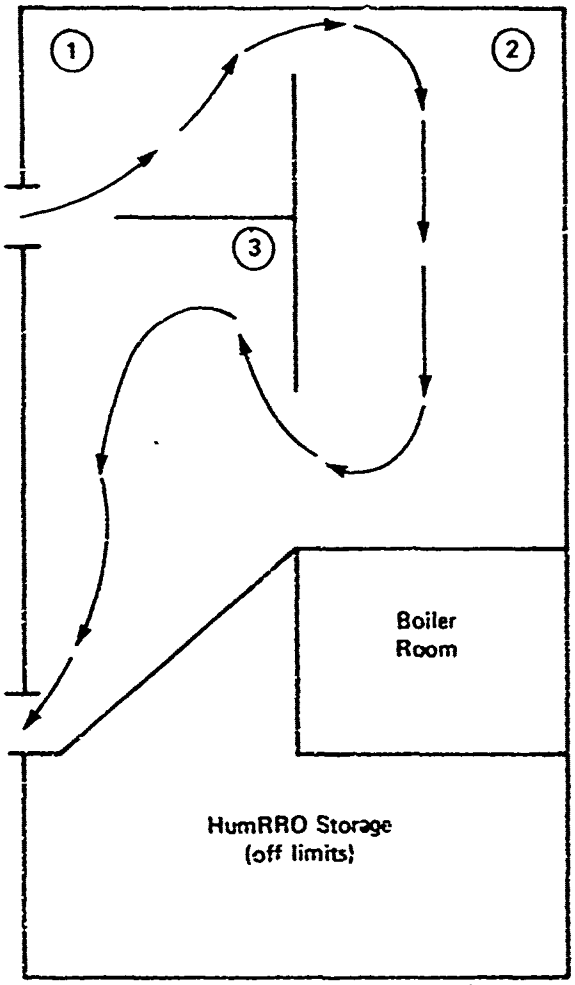
The layout for the office type building is presented in Figure 3. The furnishings for each room used are listed in Table XIX. Twelve boobytraps were located inside this building, and two were emplaced outside of the building. The types of devices, their means of activation, and their location are listed in Table XX.

The layout for the bottom floor of the residence type building is presented in Figure 4. Four rooms were on this floor: bathroom, kitchen, dining room, and living room. The furnishings for each of these rooms are listed in Table XXI. Fourteen boobytraps were located inside these rooms, and one boobytrap was placed outside the entrance to the bottom floor. The types of devices, their means of activation, and their locations are listed in Table XXII.

The layout for the top floor of the residence type building is presented in Figure 5. Five rooms were on this floor: a lounge, an open area, and three bedrooms. The furnishings for each of these rooms are listed in Table XXIII. Fourteen boobytraps were

[1]The tests are described briefly in Appendix A and in detail in an interim report to USAMERDC, "Identification and Assessment of the Human Mine Detection Factors in Built-Up Areas," (HumRRO IR-D4-74-3).

Civilian Office Environment Test Course



Note: The arrows indicate the general path the subjects followed.

Figure 3

located inside these rooms, and one boobytrap was placed on the stairs leading up to this floor. The types of devices, their means of activation, and their locations are listed in Table XXIV.

Subjects completed the proficiency test in three parts. The first and fifth subjects in each subgroup started the criterion test in the residence-type building and finished it in the office-type building. All other men started the test in reverse order. Testing in the residence-type building began on the first floor and finished on the second floor. This schedule allowed for the completion of the criterion test within a time frame of about 1.5 hours for each set of five subjects.

During the test, the men wore fatigues, boots, helmets, and a web belt with poncho and canteen. In addition, each carried an M16A1 rifle. The test was completed individually at the subject's own pace.

Prior to starting the proficiency test, the men received a 15-minute period of instruction on detecting mines and boobytraps in built-up areas. This instruction covered

Table XIX

Furnishings in Office Environment

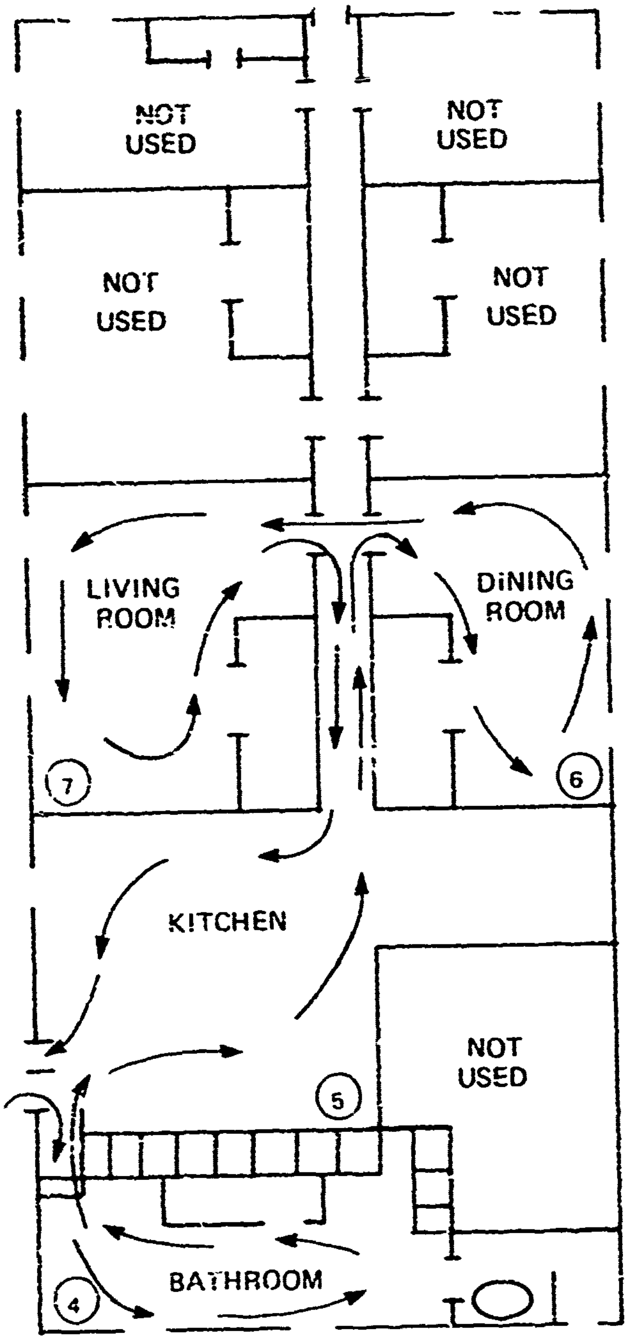
Furnishings	Room 1	Room 2	Room 3
Chairs			
Desk	1	1	2
Small	1	1	1
Tables			
Small	0	0	1
Large	0	1	0
Desks	1	1	2
Bookcase	1	0	1
File cabinets	1	1	0
Lamps	1	1	3
Rugs	1	0	1
Out boxes	1	0	1
Fan	0	0	1
Easel	0	0	1

Table XX

List of Devices, Means of Activation, and Location Employed in Office Environment

Room No.	Device	Means of Activation	Location
Outside	M1A1	Pressure	Under 3rd step at entrance
1	M1A1	Pressure	Behind entrance door
1	M1A1	Pressure	Under rug on floor
1	M5	Pressure release	In filing cabinet drawer
1	Explosive	Electrically	In lamp on desk
2	M5	Pressure release	In telephone on desk
2	M1A1	Pressure	On floor in front of desk
2	M1A1	Pressure	In chair seat behind desk
2	M1	Tripwire	Wire from partition to wall
3	M5	Pressure release	Under lamp on small table
3	M1A1	Pressure	Under rug
3	M1	Tripwire	Wire from desk to wall
3	M5	Pressure release	On bottom of window near door
Outside	M1	Tripwire	Across outside steps to bush

Civilian Living Quarters
Test Course: Bottom Floor



NOTE The arrows indicate the general path the subjects followed

Figure 4

Table XXI

Furnishings in Residence Environment: First Floor

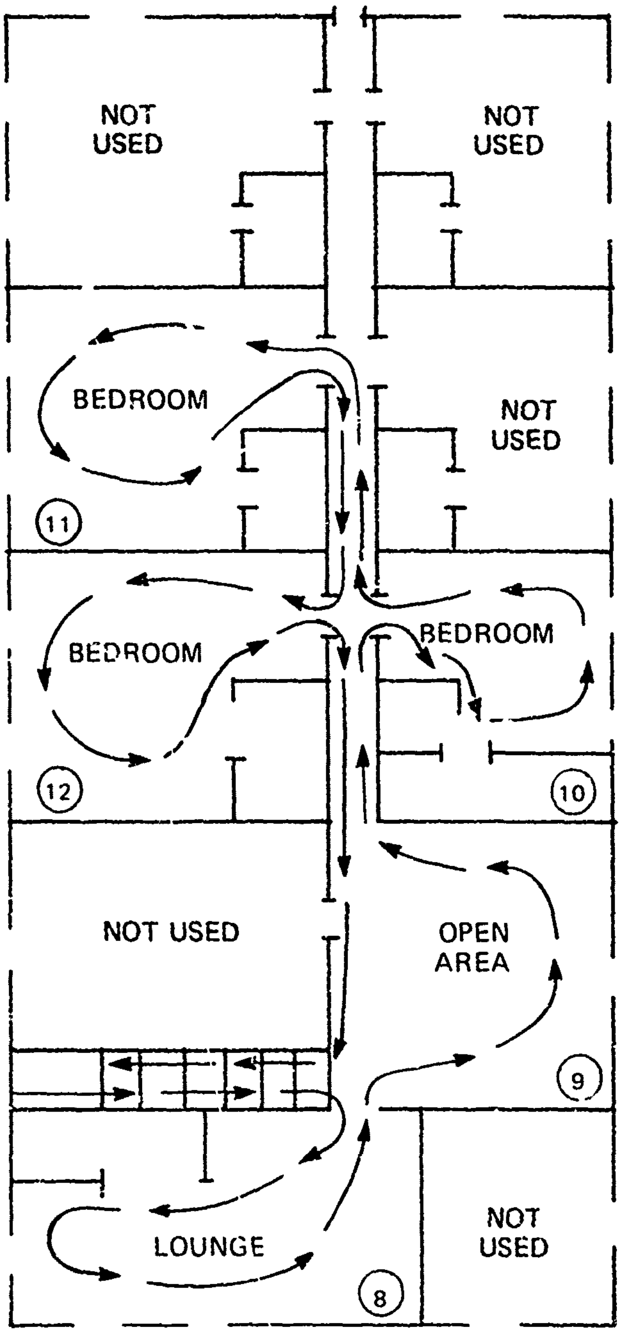
Furnishings	Room 4	Room 5	Room 6	Room 7
Chairs				
Small	0	0	5	1
Medium	0	0	0	1
Tables				
Small	0	1	0	0
Medium	0	1	1	0
Coffee table	0	0	0	1
Desks	0	0	0	1
Bookcase	0	0	0	1
Lamps	0	0	0	2
Rugs	0	1	1	1
Television	0	0	0	1
Sofa	0	0	0	1
Water fountain	0	1	0	0
Small stove	1	0	0	0
Toaster	0	1	0	0

Table XXII

List of Devices, Means of Activation, and Location Employed in Residence Environment: First Floor

Room No.	Device	Means of Activation	Location
Outside	M1A1	Pressure	Under step
Outside	M1	Pull	Inside screen door
4	Explosive	Pressure activated electrical switch	Behind toilet
4	M1	Tripwire	Inside shower curtain
5	M5	Pull	Inside bottle on table
5	M1	Pull	Inside drawer
5	M1	Pull	Inside dish cabinet
6	M1	Pull	Behind door
6	M1A1	Pressure	Under rug
6	M1	Tripwire	Wire from chair to closet
6	M5	Pressure release	Between chairs at table
7	M5	Pressure release	Under seat in lounge chair
7	M5	Pressure release	Behind TV
7	Explosive	Electrical	In lamp on bookcase
7	M5	Pressure release	In "Sex" book in bookcase

Civilian Sleeping Quarters
Test Course: Top Floor



NOTE: The arrows indicate the general path the subjects followed.

Figure 5

Table XXIII

Furnishings in Residence Environment: Second Floor

Furnishings	Room 8	Room 9	Room 10	Room 11	Room 12
Chairs					
Small	1	2	2	1	3
Medium	1	0	0	0	0
Tables					
Small	0	0	2	1	1
Medium	0	1	0	0	0
Large	1	0	0	0	0
Desks	0	0	0	1	1
Bookcase	0	0	0	0	1
Rugs	0	1	0	1	0
Bed with mattress	0	0	1	1	1
Sofa	1	0	0	0	0

Table XXIV

List of Devices, Means of Activation, and Location Employed in Residence Environment: Second Floor

Room No.	Device	Means of Activation	Location
Stairwell	M1A1	Pressure	Under 2nd stair on stairs to second floor
8	M1A1	Pressure	Back of door
8	M1	Pull	Under small folding chair
8	M5	Pressure release	Under sofa cushion
9	M1A1	Pressure	Under rug
9	M1	Tripwire	Across top of stairs
10	M5	Pressure release	Under mattress
10	M5	Pressure release	Under leg of chair at table
10	M1	Tripwire	Behind curtain in closet
11	M1	Tripwire	In left side of clothes closet
11	Explosive	Electrically	In upper part of window
11	Explosive	Electrically	In ceiling light
12	M5	Pressure release	Under bookcase
12	M5	Pressure release	Between chair and table
12	M1A1	Pressure	Under top left corner of bed

the types of devices likely to be encountered in built-up areas, methods of employment, cues likely to suggest the presence of these devices, and appropriate search techniques. Examples of the specific types of devices likely to be encountered during the test were shown the subjects, and their operation was explained.

Next, the men were briefed on the nature of the tactical situation presented by the test. Subjects were told to assume they were part of a company that had moved into a built-up area from which an enemy force had recently withdrawn after token resistance. It was explained that this enemy was suspected of having placed mines and boobytraps in the area before its retreat. Next, they were told their platoon had been given the mission of clearing a number of buildings which would be used as a battalion headquarters. Finally, it was explained that they were to go through certain designated buildings and detect and mark any mines or boobytraps left by the enemy. They were further told that EOD personnel would eventually dispose of the devices they had detected.

Subjects were then given guidance concerning the procedure to be followed during their detection effort. They were told there would be a pre marked path to follow through each of two buildings although they could deviate from the path to investigate suspected areas. It was explained that they could touch objects when this was necessary to supplement their visual search effort. Subjects were told they could move through the buildings at any pace they considered appropriate.

After the test procedures were explained to the men, they were taken to a holding area. They were then called from the holding area to an appropriate test site as space became available. Before the subject entered the area, the evaluator reviewed the test procedures with him and asked him if he had any questions about what he could and could not do during the test. Questions were answered. The test for that area was then begun.

As the subject moved from the starting point for each part of the test, an evaluator started a stopwatch and maintained a position behind the subject where he could closely observe the search procedure. When a subject stopped and pointed out a location he thought contained a mine or boobytrap, the evaluator performed the following actions:

(1) Stopped the stopwatch.
(2) Asked the subject for the basic clue he felt indicated the presence of a device.
(3) Measured the distance from the evaluator to the suspected device.
(4) Entered the elapsed time, the basic clue, and the distance measure on the subject's evaluation form.
(5) Repaired any disturbance to the mine or boobytrap.
(6) Reset the stopwatch.

When a device was activated, the evaluator made a notation to this effect on the subject's evaluation sheet. When a subject made a false detection—that is, indicated a device was present when it actually was not—the evaluator acted as if a device was present and collected the appropriate information. This information and the fact the detection was false were then entered on the subject's evaluation form.

Immediately after completing each part of the test, the subject rated the level of effort he felt he had put forth during that part of the test. Simultaneously, the evaluator independently rated the level of effort he had observed the subject manifesting during that part of the test. The same five-point scale (unsatisfactory, fair, good, very good, and outstanding) was used for both of these ratings. Both subjects and evaluators were instructed to base their ratings on how hard they thought the subjects were trying, not on detection success.

Also for each part of the test, evaluators indicated for each subject the type of search technique employed by the subject during the completion of the test. The response alternatives listed in Table XXV were used in this evaluation.

Table XXV

Search Technique Categories Used by Evaluators to Describe Individual Search Strategies Employed by Subjects

Category A

Searched floor primarily
Searched furnishings primarily
Alternated between searching floor and furnishings

Category B

Searched suspected areas only
Searched all areas systematically

Category C

Searched on, in, and under furniture

Category D

Used sense of touch to supplement visual detection

After each part of the criterion test had been completed and all individual difference data had been collected, subjects were dismissed. Each subject was used only once during this study.

RESULTS

Human Factors Data Analysis

One hundred subjects produced a total of 3134 detections during the completion of the proficiency test. Of these detections, 3090 (98.6%) were true detections—that is, a simulated mine or boobytrap emplaced in or around the buildings was detected. The remaining 44 detections (1.4%) were false detections—that is, a device was said to be present when no device was actually there. The average detection rate was 70.2 percent (SD = 13.4). The average miss rate was 22.2 percent (SD = 11.6) and the average activation rate was 7.6 percent (SD = 3.8) per subject.

The detection, miss, and activation rates of each device were calculated. Inspection of these statistics indicated that the simulated devices could be divided into two categories: (a) devices detected or missed, but seldom or never activated (Detected/Missed Devices) and (b) devices detected or activated, but seldom or never missed (Detected/Activated Devices). Most devices (84.1%) were in the first category. Tables XXVI and XXVII list the devices in each category, as well as their detection, miss, and activation rates.

Evaluation of the devices in each category revealed that those in the Detected/Missed category generally were emplaced inside, under, between, or behind objects off the path on which subjects advanced. Those in the Detected/Activated category generally were emplaced in such a manner that they intersected and crossed the path on which the men advanced.

Table XXVI

Mean Detection, Miss, and Activation Rates for Devices Seldom or Never Activated

(Percent)

Device	Detection Rate	Miss Rate	Activation Rate
M1A1 hidden under a floor rug	98	2	0
M1 with tripwire in closet at shoulder height	98	2	0
M1 with tripwire behind curtain in closet	97	3	0
M1A1 hidden under a floor rug	96	4	0
M1A1 hidden under desk chair seat	96	4	0
M1A1 hidden under a floor rug	96	3	1
M1 with tripwire from desk to wall across subject's path	94	6	0
M5 between two table chairs	94	5	1
M1 under folding chair	93	7	0
M1A1 under mattress on bed	92	8	0
M5 between chair and table	92	8	0
M5 under bookcase on floor	91	7	2
M5 under mattress on bed	87	13	0
M5 under sofa cushion	86	13	1
M1A1 under floor rug	83	17	0
Explosive under toilet water tank	82	18	0
M1 inside shower stall curtain	80	19	1
M5 under stuffed chair seat	80	19	1
M1A1 behind door	78	22	0
M1 inside dish cabinet	78	22	0
Explosive in lamp on bookcase	78	22	0
M5 under lamp on desk	75	24	1
M1 inside drawer on table	73	27	0
M5 behind television	72	28	0
Explosive in lamp on desk	66	34	0
M1A1 behind door near lower hinge	62	35	3
M5 under leg of table chair	61	39	0
M5 in book in bookcase	53	46	1
M5 inside bottle on table	51	49	0
M1A1 on floor	51	40	9
M5 between window and frame	48	52	0
M5 in desk telephone	44	56	0
M1 behind door	40	59	1
M1A1 under 2nd step at entrance to home environment	39	51	10
Explosive in upper part of window	32	68	0
Explosive in ceiling light	22	78	0

Table XXVII

Mean Detection, Miss, and Activation Rates for Devices Seldom or Never Missed
(Percent)

Device	Detection Rate	Miss Rate	Activation Rate
M1 with tripwire across top of stairway used by subject to get to 2nd story of home environment	85	0	15
M1 with tripwire from chair to closet across subject's path	81	0	19
M1A1 under step at entrance of office environment	60	4	36
M1 with tripwire from desk to wall across subject's path	51	6	43
M1 with tripwire from step to bush at exit from office environment	40	9	51
M1 behind screen door	39	1	60
M1A1 under 2nd stair on stairway - used by subject to get to 2nd story of home environment	25	3	72

In the Detected/Missed category, detection rate appeared to be related to the way in which simulated devices were hidden (see Table XXVIII). Devices with a low (less than 50%) or medium (50% to 79%) detection rate were generally hidden either inside, behind, or between objects in the testing area. Devices with a high (80% or greater) detection rate were generally hidden under objects in the testing area. In the Detected/Activated category, devices with a low or medium detection rate were less exposed than those with a high detection rate.

To study the relationship between detection rate and clues stated by subjects as assisting in their detection for each category of simulated device, the percentage of times each of the 11 clues were employed was calculated for low, medium, and high detection rates. These results are presented in Table XXIX. For devices in both categories, an exposed triggering device was the primary clue at all detection rates.

These results suggest that the detection of devices in the Detected/Missed category was mediated by subjects' orienting toward likely hiding places off their path of advance. The detection of devices in the Detected/Activated category appeared to be mediated by how visible these devices were on the path of advance. In both cases, it would appear that once the men were oriented toward a device, the primary basis for a detection was an exposed triggering device.

Analysis of Detection Distance Data

When a simulated device was detected, the evaluator used a yardstick to measure the distance of the subject from the device at the time of detection. From these data, the average detection distance was calculated for each device. These results are presented in Table XXX. Next, for each category of simulated device, a correlation was obtained between the average detection rate and the average detection distance. For Detected/Missed Devices, the correlation between average detection rate and average detection

Table XXVIII

Frequency of Each Method of Using Devices for Detected/Missed and Detected/Activated Devices for Low, Medium, and High Detection Rate

Method of Hiding	Detected/Missed Device	Detected/Activated Device
Low Detection Rate		
Exposed triggering device	1	2
Under object	12	0
Behind/between objects	2	0
Inside objects	3	0
Medium Detection Rate		
Exposed triggering device	1	1
Under object	2	1
Behind/between objects	3	0
Inside objects	7	0
High Detection Rate		
Exposed triggering device	0	1
Under object	1	1
Behind/between objects	2	1
Inside objects	3	0

Table XXIX

Percent of Times Each Detection Clue was Used for Detected/Missed and Detected/Activated Devices for High, Medium, and Low Detection Rates

Clue	Detection Rate		
	Low	Medium	High
Detected/Activated Devices			
Out-of-place object	3.0	--	.6
Object designed to attract special interest	--	--	--
Unnatural condition of furnishings	3.0	29.4	--
Exposed portion of simulated device	11.1	2.8	2.4
Exposed portion of triggering device	65.7	54.1	95.8
Material used to conceal device	--	.9	--
Continued use of same technique	--	--	--
Anticipated Location	3.0	.9	--
Variation in device color	--	11.0	1.2
Variation in shape	--	--	--
Variation in texture	14.2	.9	--
Total	100.0	100.0	100.0

(Continued)

Table XXIX *(Continued)*

Percent of Times Each Detection Clue was Used for Detected/Missed and Detected/Activated Devices for High, Medium, and Low Detection Rates

Clue	Detection Rate Low	Medium	High
Detected/Missed Devices			
Out-of-place object	13.7	3.8	9.2
Object designed to attract special interest	--	6.0	.6
Unnatural condition of furnishings	14.2	4.6	26.1
Exposed portion of simulated device	20.2	38.3	23.6
Exposed portion of triggering device	44.2	43.2	34.9
Material used to conceal device	.4	.1	.4
Continued use of same technique	--	.6	.8
Anticipated location	5.6	3.1	3.7
Variation in device color	1.7	.1	.4
Variation in shape	--	.2	--
Variation in texture	--	--	.3
Total	100.0	100.0	100.0

Table XXX

Mean and Standard Deviation of the Detection Distance for Each Simulated Mine and Boobytrap Device

Device	How Employed[a]	Average Detection Rate	Detection Distance (Inches) $\overline{X}$	SD
Inside screen door	B	40	3.0	2.6
In book in bookcase	I	53	3.0	3.3
Inside bottle	I	51	5.2	4.2
Inside dish cabinet	I	78	5.3	1.4
Under chair leg	U	80	5.8	3.5
Inside shower stall	I	80	6.4	4.5
In lamp on bookcase	I	78	7.9	17.5
Under step	U	25	8.8	8.7
Under step	U	39	10.3	6.1
Under toilet tank	U	82	12.6	6.1
Under rug	U	96	13.5	8.4
Behind television	B	72	13.6	6.1
In filing cabinet drawer	I	51	14.8	14.2
Tripwire from cabinet to closet	ETD	81	19.4	21.6
Tripwire from step to bush	ETD	39	20.1	21.7

(Continued)

Table XXX *(Continued)*

Mean and Standard Deviation of the Detection Distance for Each Simulated Mine and Boobytrap Device

Device	How Employed[a]	Average Detection Rate	Detection Distance (Inches) $\bar{X}$	SD
Between window and frame	B	48	21.4	13.1
Inside drawer	I	73	21.7	8.4
Behind door	B	40	23.5	13.7
In telephone	I	44	25.6	19.2
On floor in front of desk	ETD	51	25.6	20.6
Inside closet curtain	I	97	25.9	14.1
Under step	U	60	27.3	10.7
In upper part of window	I	32	27.8	14.3
In desk chair	I	96	31.4	14.2
In clothes closet	I	98	31.5	11.2
Tripwire from desk to wall	ETD	51	31.8	21.6
Under bookcase on floor	U	91	32.4	15.3
Under rug	U	83	33.3	17.0
Behind door	B	78	33.3	18.1
Between table and chair	B	94	33.7	24.0
Behind door	B	62	34.9	8.9
Between chair and table	B	92	35.4	14.5
Under chair	U	93	38.5	23.6
Tripwire from desk to wall	ETD	94	38.6	19.4
Under lamp	U	75	41.0	27.8
Under mattress	U	92	41.2	15.7
Under mattress	U	87	41.3	10.8
Under rug	U	96	43.0	28.7
Under sofa cushion	U	86	43.7	25.9
In desk lamp	I	66	44.4	39.6
Under chair leg	U	61	47.2	22.7
Tripwire across step	ETD	85	52.8	24.8
Under rug	U	98	57.6	37.1
In ceiling light	I	22	62.3	23.9

[a]B - hidden behind/between object, I - hidden inside of object; U - hidden under object; ETD - hidden with exposed triggering device.

distance was .16 (df = 35, NS), while this correlation for Detected/Activated Devices was a .71 (df = 5, $.05 < p < .10$). In both cases the correlation was not significant. However, there was a tendency for average detection rate to be related to the average detection distance for Detected/Activated Devices. This latter trend supports the suggestion that for Detected/Activated Devices, level of visibility was an important factor in their detection.

Analysis of the False Detection Data

Of the 100 subjects who completed the proficiency test, 22 subjects produced 44 false detections. The average number per subject producing false detections was 2.0 (SD = 1.7). The average number over all men completing the proficiency test was .4 (SD = 1.1). False detections were a very low probability event. This was also true for the *Task B* field mine and boobytrap proficiency test.

All false detections were made in the office environment. This was unexpected, since false detections produced during the *Task B* field testing had occurred in all environments studied. Since some men started the test in the office environment while others started it in the home environment, it was hypothesized that the different starting points may have affected the production of false detections in the office environment. To test this hypothesis, subjects were divided into two groups: those producing false detections (N = 22) and those not producing false detections (N = 78). Next, each of these groups was further subdivided into those subjects who started the test in the office environment and into those who started the test in the home environment. Finally, a Chi-Square test of association was performed on the data to determine if there was a relationship between test starting point and whether or not false detections were produced in the office environment. A Chi-Square test (0.50, df = 1) was not significant. This result indicated that there was no relationship between test starting point and false detection product.

Another possibility was that the evaluator for the office environment had a different criterion for accepting subjects' responses as false detections than did the evaluators in the home environment. Interviews with the evaluators produced no evidence to support this hypothesis.

Thus, the basis for the differential production of false detections by subjects in the present study is unclear. It may be an experimental artifact or it may be that false detections are a characteristic of office environments and not of home environments. Further research will be required to study this problem.

Analysis of Search Techniques Employed by Subjects

The search technique employed by the men in each test environment was assessed by the evaluators using a check list. To determine whether detection rate varied according to the search technique employed, the average detection rate was computed for each of the following: A—searched floor primarily, B—searched furnishings primarily, C—alternated between searching the floor and the furnishings, D—searched suspected areas only, E—searched all areas systematically, F—searched on, in, and under furniture, and G—used sense of touch. The results of these computations are presented in Table XXXI. From a review of this table, several trends in the data were identified.

Considering techniques A, B, and C as defining a search technique category, it is clear that technique C (alternated between searching floor and furnishings) was favored most frequently by the men. Also, for these three techniques, C was associated with the highest average detection rate in each test environment.

Considering techniques D and E as defining a search technique category, it is clear that there was more of a tendency for technique E (searched all areas systematically) to be associated with higher average detection rates than for technique D. Also, use of this

Table XXXI

Detection Rate as a Function of Search Techniques Used by Subjects for Each Test Environment

Search Technique[a]	Office Environment			Living Quarters			Sleeping Quarters		
	%	$\bar{X}$	SD	%	$\bar{X}$	SD	%	$\bar{X}$	SD
A	0	--	--	2.2	3.5	.7	1.1	4.0	0
B	40.2	7.5	1.8	8.6	7.1	1.6	41.1	10.7	1.8
C	59.8	10.3	2.2	20.4	9.2	19.0	57.8	12.9	.5
D	54.6	8.1	1.9	7.5	9.0	1.8	40.0	10.6	1.4
E	27.8	11.0	1.7	[illegible]	11.6	2.2	53.7	12.2	1.3
F	24.7	10.4	3.0	2.2	11.0	1.4	91.6	11.7	1.4
NonF	75.3	8.8	2.1	97.8	10.4	2.8	8.4	9.6	2.7
G	13.4	11.0	2.6	1.1	12.0	0.0	47.4	12.0	1.7
NonG	86.6	8.9	2.3	98.9	10.4	2.7	52.6	11.1	1.4

[a]A Search floor primarily
B Searched furnishings primarily
C Alternated between searching floor and furnishings
D Searched suspected areas only
E Searched all areas systematically
F Searched on, in, and under furniture
NonF Did not search on, in, and under furniture
G Used sense of touch
NonG Did not use sense of touch

technique appeared to depend upon the test environment More men employed technique E in the home environment (living and sleeping quarters) than in the office environment. These results suggest that had more subjects adopted technique E in the office environment, the average detection rate for this environment probably would have been higher.

Use of technique F (searched on, in, and under furniture) also depended upon the test environment. It was used by over 90 percent of the subjects in the sleeping quarters environment, while only 2.2 and 24.7 percent of the subjects used it in the living quarters and the civilian office environments, respectively. Further, use of this technique appeared to be associated with higher average detections. These results suggest that had more subjects used technique F in the office and living quarters environments, the average detection rates for these environments probably would have been higher.

Use of Technique G (used sense of touch) was generally low across test environments. However, its use appeared to be associated with higher average detection rates. This result suggests that detection performance probably would have been improved across the test environments if more men had used touch to aid in their detection effort.

These results, considered together, suggest for the *Task F* study, the best search technique was to alternate between searching the floor and furnishings, to search all areas systematically, to search on, in, and under furniture, and to use the sense of touch to aid in the performance of the detection task. Due to the small number of subjects appearing in some of the categories in Table XXI, it was not appropriate to perform statistical analyses to determine whether any true differences existed among the categories of search

techniques. As a consequence, only the observed trends were discussed. Further research with statistically adequate numbers of subjects employing various combinations of these techniques will be required to establish the true validity of these results and their implications.

Individual Difference Data Analysis

A multiple regression equation involving the predictors measured by the test battery developed in the FY 73 IDENTIFY research was developed from the data collected during the present study. The regression weights and percent of criterion variance accounted for by each measure are presented in Table XXXII. The multiple correlation between the weighted combination of these variables and the criterion was .86 ($p < .01$, $df = 8, 72$). The total criterion variance accounted for was 74 percent. However, 70 percent of the total variance was accounted for by only one measure, the average of the evaluators' effort ratings. The other measures in the equation together accounted for the remaining 4 percent. This result indicates that for this set of measures the average of the evaluators' ratings was the primary predictor of the total number of detections occurring in the built-up area. This suggests that the predictor test battery developed during Fiscal Year 1973 IDENTIFY research cannot be used to predict detection performance in a built-up area.

Table XXXII

Percent of Criterion Variance Accounted for by Each Measure in IDENTIFY *Task C* Predictor Battery for Both *Task B* and *Task E* Samples

Variable	Percent Criterion Variance Accounted for by *Task B* Equation	Percent Criterion Variance Accounted for by *Task C* Equation
Speed of Movement During		
Search/Course Length	28.6	0.7
Effort Expended During Search	17.9	70.0
Education		
Years of Civilian Education Completed	2.4	0.0
H.S. Diploma	3.5	-0.2
H.S. Diploma Secured by GED Test	1.2	0.0
Activities Participation	2.5	3.5
Level of Dogmatism	1.4	-0.2
Binocular Visual Acuity	0.5	0.2
All Measures Together	58%	74%
Multiple *R*	.76	.86

Table XXXIII presents the correlation matrix for the individual difference and performance test measures for the 81 subjects who completed all phases of the testing. GT score was not included in this matrix, since these scores were available for only 58 men. When several measures of variable were available for a single subject, the average of these was used for this analysis.

A factor analysis of the matrix of intercorrelations is presented in Table XXXIV. The factor analysis model was a principal components solution with a varimax rotation.

Table XXXIII

Correlations[a] Among Individual Difference and Performance Test Measures

		RB	HFT	EFT	RFT	Dm	HSD	GED	CE	AMS	TOI	HST	CPT	AD	BVA	AP	SER	EER	TT	TD	TM	TA	FD
RB	Racial Background	--																					
HFT	Hidden Figures Test	.05	--																				
EFT	Embedded Figures Test	.38	.38	--																			
RFT	Rod and Frame Test	.40	.08	31	--																		
Dm	Dogmatism	04	.08	.10	.23	--																	
HSD	High School Diploma	05	.18	23	.04	.08	--																
GED	*	.03	.02	.11	.06	10	40	--															
CE	Civilian Education (Years)	01	.17	.21	.08	.04	.70	.02															
AMS	AM Scale	.19	.02	.26	03	.07	.03	.24	.24	--													
TOI	Task Orientation Inventory	12	.26	.17	17	.06	.06	11	.04	.30	--												
HST	Hand Skills Test	.04	.24	.32	14	01	.12	.08	07	.22	.18												
CPT	Color Perception Test	13	.17	.24	.03	.13	.17	10	14	.25	.12	.12	--										
AD	Acuity Disparity	18	.07	.04	.08	.09	.11	.09	.16	.12	.06	.06	.14										
BVA	Binocular Visual Acuity	.01	.06	.00	05	.03	.03	09	.00	.02	.02	02	.12	.13	--								
AP	Activities Participation	.29	.03	24	.18	.07	.08	.14	.15	.11	.08	.08	.08	.04	.02	--							
SER	Average Subject Effort Rated	11	02	.05	.03	.10	.23	18	.16	.01	11	.11	.00	.18	.08	06							
EER	Average Evaluator Effort Rated	00	.04	.21	.14	14	.04	.07	.01	.00	.09	.27	.06	.14	.12	.24	.48						
TT	Total Search Time	.10	.07	12	16	.06	.03	.06	.09	-.03	21	.21	.03	.32	.40	.16	.34	.68	--				
%TD	Percent Total Detections	10	.10	.21	.16	.03	.02	00	.04	.01	11	.12	.15	.12	.01	31	.42	.84	.55	--			
%TM	Percent Total Misses	.10	.09	.20	15	.03	.02	.01	07	.01	.00	.08	.17	.11	.00	25	.45	.78	.53	.97	--		
%TA	Percent Total Activations	02	.08	.06	.09	.00	.12	.04	.09	.05	.16	.16	.03	.10	.02	.31	.14	-.58	-.32	55	.34	--	
FD	Total Number False Detections	.23	.01	.01	.03	.01	.01	12	.04	.17	.12	.14	.02	.16	.33	.05	.23	.22	.38	.14	.11	.19	--

[a]A correlation of .22 magnitude or higher (positive or negative) is statistically significant ($df = 79$, $p < .05$).
*Securement of High School Diploma Equivalent by Completion of GED Test.

Table XXXIV

Factor Analysis of Predictor and Criterion Variables for Built-Up Area Detection

Variable	Factor I	II	III	IV	V
1. Racial Background	-.03	.04	.68	.09	.22
2. Embedded Figures Test	.13	.23	.55	.39	-.11
3. Rod and Frame Test	-.09	.00	.59	-.05	-.06
4. High School Diploma	.08	.95	-.05	-.01	.02
5. Civilian Education	-.07	.63	-.05	.27	.01
6. AM Scale	-.07	.06	.11	.64	.08
7. Task Orientation Inventory	.08	-.07	-.17	.42	.11
8. Color Perception Test	.12	.14	.07	.40	-.19
9. Binocular Visual Acuity	-.01	-.03	-.09	-.10	.55
10. Average Subject Effort Expended	.47	.02	.20	.54	.19
11. Average Evaluator Effort Expended	.90	.01	-.06	.05	.23
12. Total Search Time	.58	-.05	-.08	.04	.63
13. Total Detections	.99	-.03	.12	.08	-.03
14. Total Misses	-.83	.07	.10	-.07	.02
15. Total Activations	-.51	-.09	.09	-.06	-.10
16. Total False Detections	.14	-.03	.11	.20	.53

Five factors emerged from this analysis. (Variables that did not load .4 or above on at least one factor were excluded from this table.)

The first factor was defined by three detection performance measures (percent detections, percent misses, and percent activations), the effort measures (subject and evaluators' ratings), and search time. Both time and effort were highly correlated with this factor. Further, no other variable loaded on this factor and these variables, with the exception of time, did not load on any other factors.

The second factor was defined by the high school diploma and civilian education measures. These were not related to any other factors nor to detection proficiency.

The third factor was defined by racial background, Embedded Figures Test performance, and Rod and Frame Test performance. The two test variables are paper-and-pencil measures. This factor is similar to the test-taking factor identified in *Task G* (see Chapter 4). As was found in the *Task G* analysis, detection performance did not load on this variable. This is consistent with the position that paper-and-pencil test measures depend on performance skills which are different from those required to detect mines and boobytraps.

The fourth factor was defined by two motivational measures, achievement motivation and task orientation, and color vision test performance. Since the motivational measures and the color vision measure represent different psychological dimensions (perceptual and motivational), this factor was not thought to be meaningful. That is, it is likely this factor occurred by chance.

Finally, the fifth factor was defined by binocular visual acuity, search time, and number of false detections. Their occurrence together suggests that false detections are produced by individuals who have poor visual acuity and who are excessively cautious (hence taking more time to complete the detection task).

The most striking observation from this table is that built-up area detection performance, together with search time and effort, was independent, that is, not associated with the paper-and-pencil or other measures studied in *Task E*. This result is in general agreement with those to be reported in Chapter 4 for field detection performance. These findings strongly suggest that detection performance is probably not predictable from knowledge of individual difference measures which are not performance oriented.

For the 58 subjects for whom GT scores were available, the correlations between GT score and the detection performance measures were computed (see Table XXXV). None of the detection performance measures was correlated significantly with GT score.

Table XXXV

Correlation of GT Test Score With Detection Performance

Detection Performance Measure	*r*	*df*	*p*
Percent Total Detections	-.07	56	NS
Percent Total Misses	.15	56	NS
Percent Total Activations	-.13	56	NS
Total False Detections	-.16	56	NS

Chapter 3

TASK F: MINE DETECTION FACTORS IN VEHICULAR OPERATIONS

BACKGROUND

Through the years armies have attempted to increase their ground mobility by conducting vehicle-mounted operations. Opposing forces have tried to restrict this capability by employing mines and boobytraps. One technique for countering the use of these devices is to place individuals on a moving vehicle in a position from which they can observe and search visually for mines and boobytraps.

This is admittedly a very difficult task. However, combat-experienced individuals have reported that devices were visually detected in Vietnam by mounted personnel. Moreover, in tests run by Picatinny Arsenal, moving tank-mounted personnel, attempting to detect surface-laid mines, exhibited a visual detection capability.[1]

The purpose of *Task F* was to identify and assess the human mine detection factors involved in vehicular operations, both along an established road and in a cross-country setting. This was accomplished through field tests of military personnel, using three types of vehicles.

APPROACH TO THE PROBLEM

Design

The overall design for this study was a 3 x 3 repeated measurements factorial design. The between-subjects variable was the type of vehicle from which the detection task was completed (jeep, APC, or tank). The within-subjects variable was the type of course completed (road course, hasty minefield course, and deliberate minefield course).

Subjects

A total of 72 subjects were tested—eight Infantry AIT graduates each day for the nine working days of the test period. Each man was tested once. Each wore fatigues, a helmet, and a web belt with poncho, and carried a canteen.

Vehicles

Subjects observed from three types of vehicles: A 1/4-ton jeep (M151), an armored personnel carrier (APC) (M113), and a tank (M48 or M60). Each vehicle was used for three days in the following sequence: 1/4-ton jeep (29 April, 1-2 May), APC (8-10 May), and tank (13-15 May).

[1] Bucklin, B., *et al Camp Drum Test of Mine Effectiveness*, Technical Memorandum 2C67, Picatinny Arsenal, Dover, New Jersey, December 1972.

Field Test Area

There were three test sites, either on or in the vicinity of Warner Range on the Fort Benning Military Reservation (see Figure 6). Course No. 1, established on a tank trail (road), consisted of Part A and Part B, each 500 meters long. On each part of the course and boobytraps were placed at random intervals in or along the sides of the trail, or in the vegetation along the trail. These devices were buried or camouflaged to provide a moderate degree of difficulty in detection. Figure 7 presents the types of devices and their sequence of presentation for Course No. 1.

Course No. 2 was a 50 x 120-meter, hasty minefield, with 32 surface-laid mines placed in four rows in grass (12 to 30" high). Each row contained four Teller anti-vehicular mines and four M15 anti-vehicular mines. Figure 8 presents the emplacement and sequence of the Teller and M15 mines for Course No. 2.

Course No. 3 was 50 x 160-meter field area, with 90 mines emplaced according to a specific pattern and buried in the ground. There were four types of mines in this course: 30 Teller anti-vehicular mines, 20 M15 anti-vehicular mines with tilt rods, 20 M16 anti-personnel mines, and 20 POMZ antipersonnel mines. As part of the course, a plowed strip containing five buried Teller anti-vehicular mines was established. Figure 9 presents the placement and sequence of the mines for this field.

Conduct of the Test

The subjects and vehicles reported to Warner Range at 0800 on each test day. First, the men were given a general briefing on the detection task. Next, they were assigned identification numbers. Testing was completed on the three courses according to the schedule presented in Table XXXVI.

On Course No. 1, the men were tested on each part at two vehicular speeds—5 and 15 miles per hour (mph). Experimental control among major variables was accomplished by the counterbalanced schedule shown in Table XXXVI. Individual performance measures for this course were (a) the percentage of devices detected, (b) the estimated distance to detected devices, (c) the number of false detections produced, and (d) the rated level of effort put forth by the men during the detection task.

Testing was initiated on Course No. 1 by the vehicle moving from a designated start point at the speed called for by the testing schedule. The subject occupied a seat designated as the observer's position. In the jeep this was the right front seat; in the APC it was the commander's hatch which is located in the middle of the top forward area; and in the tank it was also the commander's hatch which is located near the middle of the turret. An evaluator was stationed to the rear of the observer. When the observer detected a device on the course, he pointed to the device and notified the evaluator. The evaluator indicated on a score sheet that the device was detected and estimated the distance at detection. The evaluator also recorded the subject's false detections.

On Courses No. 2 and 3, the vehicles moved along a designated path through the field at a speed considered appropriate by the subjects. This was usually less than 5 mph. Initially, the subject indicated when he detected the forward edge of the minefield. When he made this observation, the evaluator indicated on the score sheet the approximate location of the vehicle. After this, the subject indicated his detection of individual mines by both pointing to and verbally reporting devices he saw. The evaluator then marked the detections on the score sheet. He also recorded any false detections.

Next the subject was instructed to indicate when he thought the vehicle was clear of the minefield, and the evaluator noted this location on the score sheet. Finally, the evaluator rated the subject's level of effort during the detection task.

Performance measures for Courses No. 2 and 3 were (a) the percentage of devices detected, (b) the location of the vehicle when the forward edge of the field was detected.

Warner Range Test Site Layout

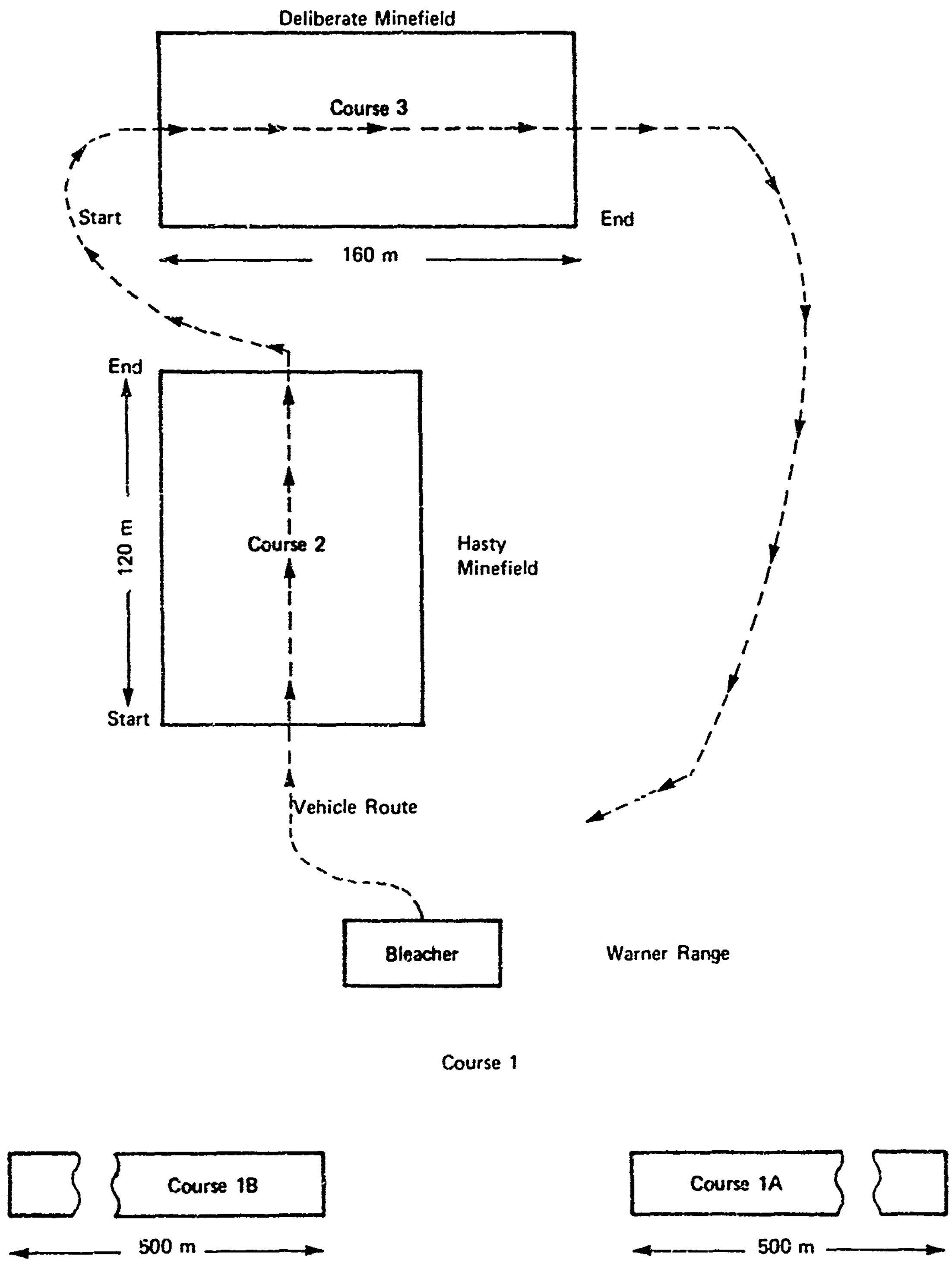


Figure 6

Detection Course No. 1: Road

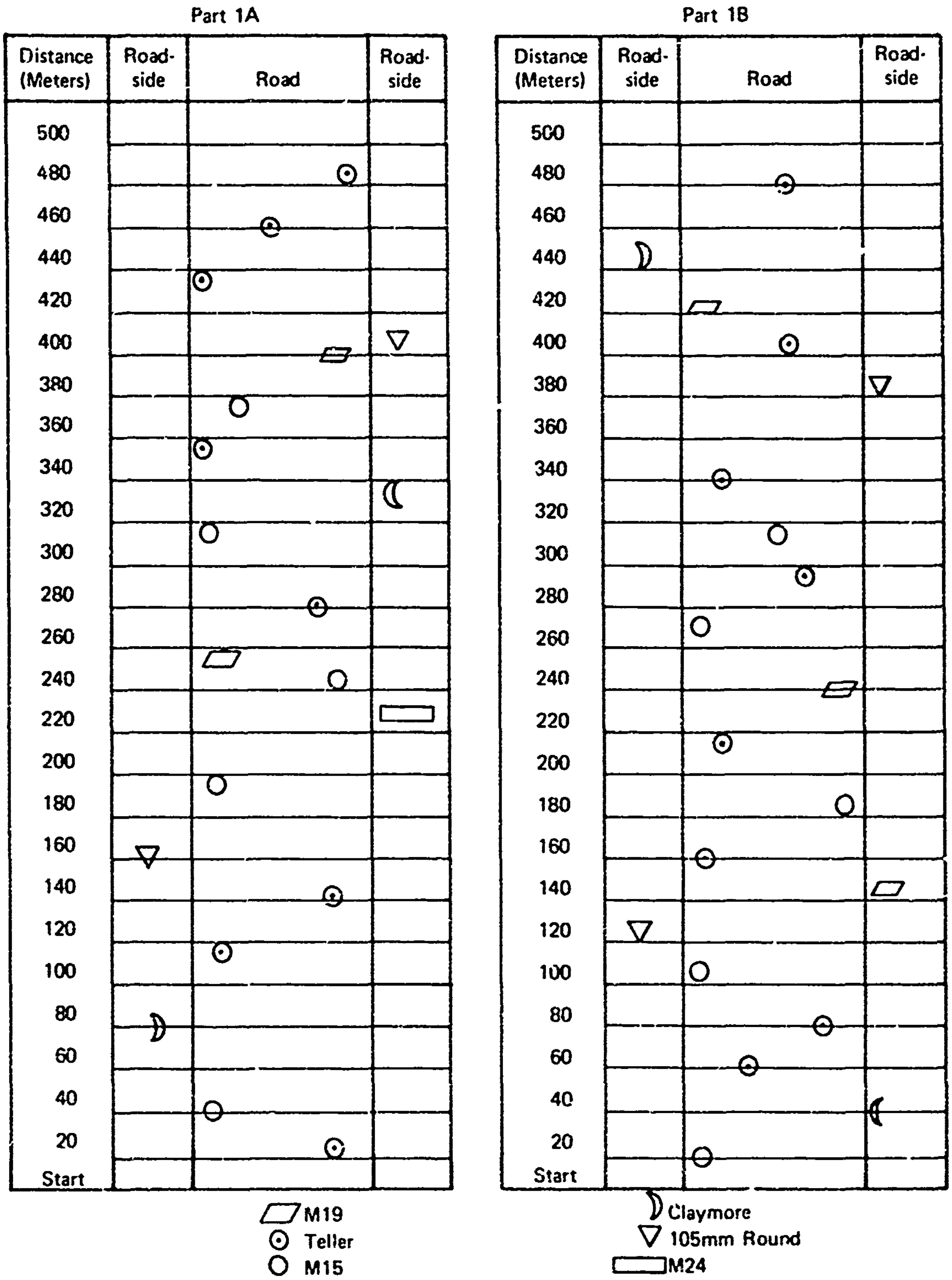


Figure 7

Detection Course No. 2: Hasty Minefield

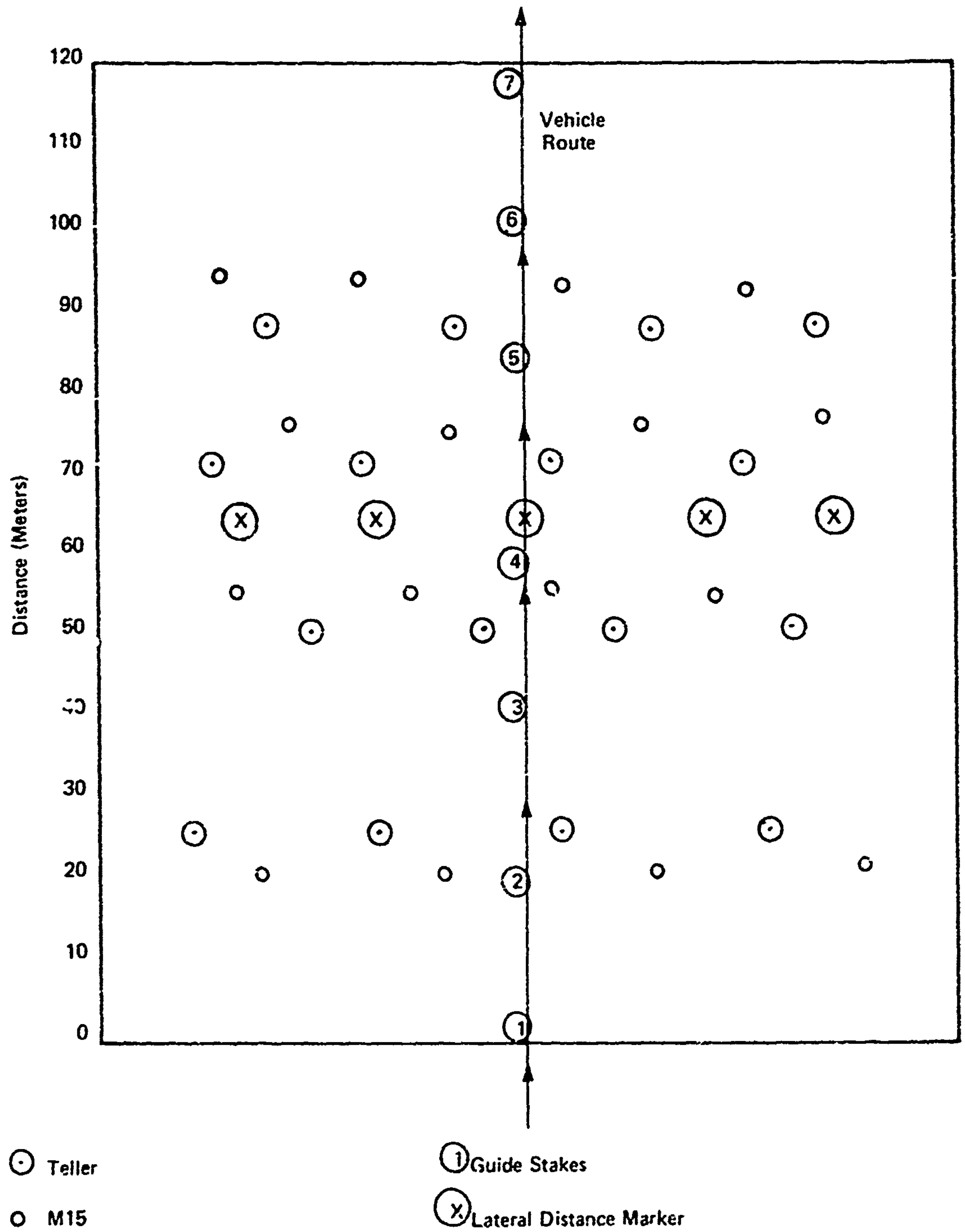


Figure 8

Detection Course No. 3: Deliberate Minefield

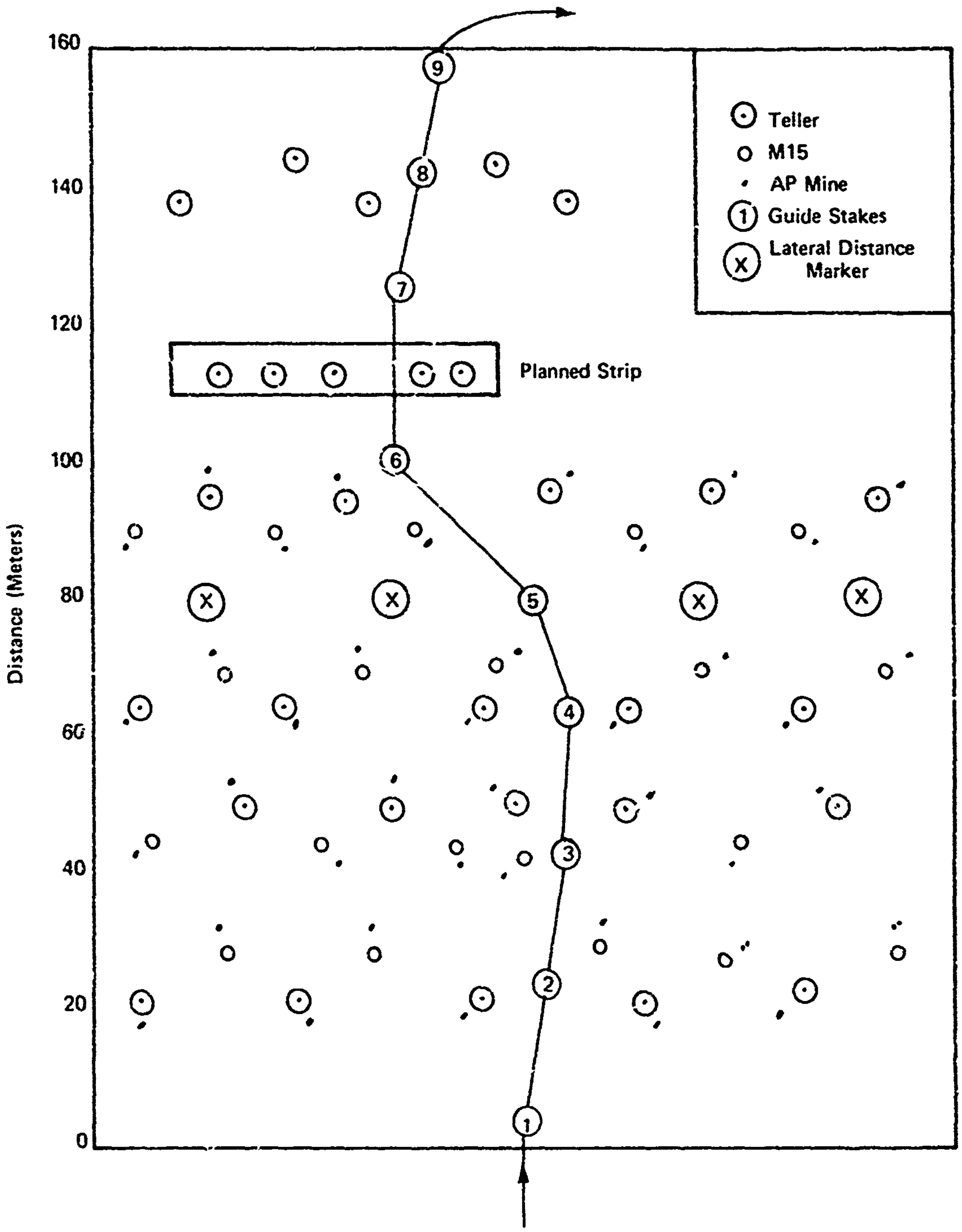


Figure 9

Table XXXVI

Schedule of Course Completion for *Task F*

Subject	Course No. 1				Course No. 2	Course No. 3
	Part A		Part B			
	5 mph	15 mph	5 mph	15 mph		
1	1st			2nd	3rd	4th
2	2nd			1st	3rd	4th
3		1st	2nd		3rd	4th
4		2nd	1st		3rd	4th
5	1st			2nd	3rd	4th
6	2nd			1st	3rd	4th
7		1st	2nd		3rd	4th
8		2nd	1st		3rd	4th

(c) the location of the vehicle when it was thought the vehicle was out of the minefield, (d) the number of false detections produced, and (e) the level of effort by the subject during the detection task.

RESULTS

Evaluation of the Effect of Vehicle and Course Type on Detection Performance

To investigate the detection performance of the men as a function of both the type of vehicle from which the detection task was performed and the type of course in which the detection task took place, a 3 x 3 repeated measurements factorial analysis of variance was conducted during the study. The dependent variable for this analysis was the percentage of devices detected by each observer on (a) the road course (Course No. 1) while traveling at 5 mph, (b) the hasty minefield course (Course No. 2), and (c) the deliberate minefield course (Course No. 3). The between-subject variable was the type of vehicle from which the detection task was performed: jeep, APC, or tank. The within-subject variable was the type of course in which the detection task took place: Course No. 1 (5 mph speed), Course No. 2, and Course No. 3.

Table XXXVII presents the results of this analysis. Only the interaction between the vehicular and course type conditions was significant ($F = 16.28$, $df = 4, 138$, $p < .01$). Thus, the data indicate that the effect a particular type of vehicle had on an observer's detection performance varied as a function of the type of course in which the detection task was performed. Figure 10 presents this interaction graphically. Tests of the simple main effects were conducted to further investigate this interaction. The results of these tests are presented in Table XXXVIII.

The simple effects test for vehicles at Course No. 1 indicated that the differences in the average detection performance among the three vehicles were significant. A multiple comparison test of the pairwise mean differences showed that jeep detection performance was significantly higher than either the APC or tank detection performance, but for these latter vehicles this performance was not significantly different.

The simple effects test for vehicles at Course No. 2, as well as for Course No. 3, showed that the differences in average performance among the three vehicles were also

Table XXXVII

Analysis of Variance of Detection Data for *Task F*

Source of Variation	df	MS	F	p
Between Subjects				
Vehicles (V)	2	313.4	<1	NS
Error (Subject x Groups)	69	328.8		
Within Subjects				
Course Type (C)	2	237.4	1.68	NS
V x C	4	2301.3	16.28	<.01
Error (C x Subjects Within Groups)	138	141.4		

Profile of Vehicle X Course-Type Interaction

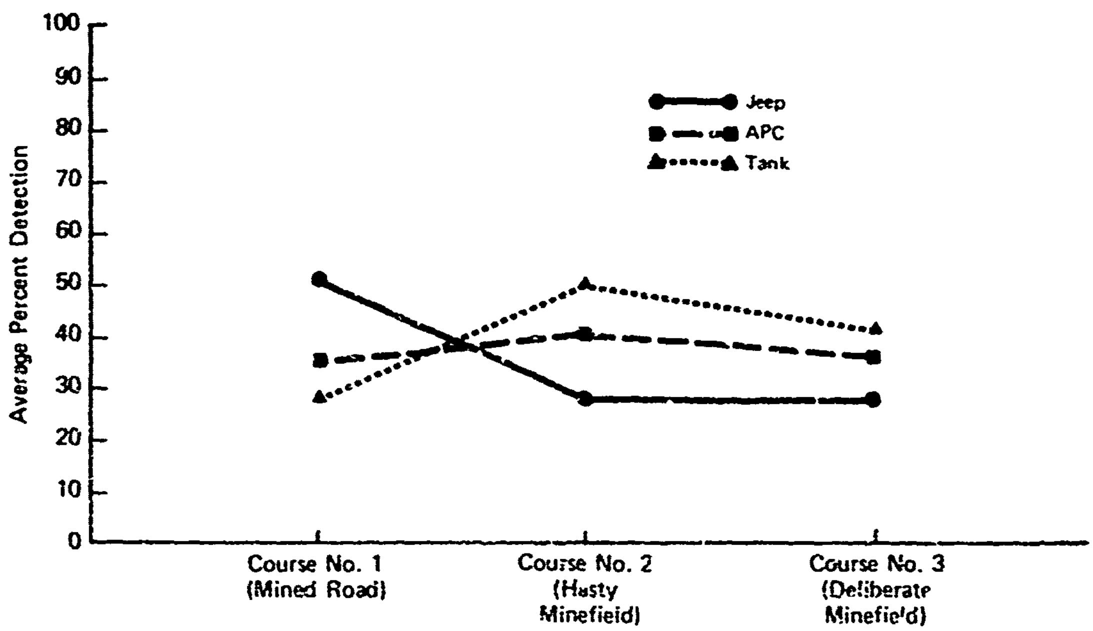


Figure 10

significant. Multiple comparison tests of the pairwise mean differences indicated that these differences were significant only for the comparisons between the jeep and tank conditions. Comparisons involving the APC condition were in each case nonsignificant.

The simple effects test for course type at the jeep and tank conditions showed that the differences in the average detection performance among the three courses were also significant. Multiple comparison tests of the pairwise mean differences indicated that, from Course No. 1 to Course No. 2, detection performance dropped significantly for the jeep, while it rose significantly for the tank. Further, these tests showed that from Course

Table XXXVIII

Analysis of Variance for Simple Main Effects for *Task F*

Source of Variation	*df*	MS	*F*	*p*
Between Subjects				
Vehicles for Course No. 1	2	2000.3	9.81	< .01
Vehicles for Course No. 2	2	1977.4	9.70	< .01
Vehicles for Course No. 3	2	938.4	4.60	< .05
Error (Within Cell)	69	203.8		
Within Subjects				
Courses for Jeep	2	2909.2	20.58	< .01
Courses for APC	2	120.3	< 1	NS
Courses for Tank	2	1810.6	12.81	< .01
Error (C x Subjects Within Groups)	138	141.4		

No. 2 to Course No. 3 the magnitude of the average detection performance did not show any significant change for both the jeep and tank.

Finally, the simple effects test for course type at the APC level was nonsignificant. This indicates that, across the three test courses, detection performance for the APC remained at essentially the same level.

Thus, these results suggest the following picture of detection performance as it occurred during the study: As the detection situation changed from a road to a field environment, jeep detection performance was affected adversely—that is, performance dropped from a high level to a lower level. On the other hand, tank detection performance was affected positively—that is, performance rose from a low level to a higher level. However, APC detection performance showed no significant variation as the environment changed from a road to a field environment. That is, detection performance for this vehicle remained at essentially the same level under both road and field conditions. This set of findings indicates that, for the vehicles studied, detection performance was optimized on the road course when detection took place from the jeep, while performance was optimized for the field courses when detection took place from a tank.

Human Factors Data Analysis—Course No. 1

Seventy-two men produced a total of 592 detections at 5 mph, and 316 detections at 15 mph. Of these 541 (91.4%) of the 5 mph detections and 304 (96.2%) of the 15 mph detections were true detections. The remaining 51 (8.6%) of the 5 mph detections and 12 (3.8%) of the 15 mph detections were false detections—that is, a device was said to be present when no device was actually there. At each speed, each man had an opportunity to detect 20 devices. The average number of detections at 5 mph was 7.5 devices (SD = 2.9), while the average number of detections at 15 mph was 4.2 devices (SD = 2.6). The average detection rate for 5 mph was 37.6 percent (SD = 14.7), while the average detection rate for 15 mph was 21.1 percent (SD = 13.2).

Table XXXIX presents detection performance (average percent detected) for each vehicular/speed combination studied. Analysis of variance showed that the differences among vehicles, as well as the differences between speeds, were significant ($F = 12.8$, $df = 2, 69$, $p < .01$; and $F = 96.3$, $df = 1, 69$, $p < .01$, respectively). The vehicle X speed interaction was also significant ($F = 4.2$, $df = 2, 69$, $p < .05$).

Table XXXIX

Average Percent Detected and Standard Deviation for Each Vehicular Speed

Vehicular Condition	Speed			
	5 mph		15 mph	
	$\overline{X}$	SD	$\overline{X}$	SD
Jeep (M151)	47.7	12.2	25.0	13.8
Armored personnel carrier (M113)	35.0	10.8	24.6	12.2
Tank (M48 or M60)	30.0	15.1	13.4	10.1
Total	37.6	14.7	21.1	13.2

Inspection of the interaction showed that as speed was increased from 5 to 15 mph, both jeep detection performance (which was highest at 5 mph) and tank detection performance (which was lowest at 5 mph) dropped at a faster rate than did APC detection performance (which was between jeep and tank detection performance at 5 mph). This result indicates that while increased speed adversely affected detection performance for all vehicles, it had less of an adverse effect from the APC on Course No. 1.

Figure 11 shows detection performance as a function of the relative location of devices on the road course for each type of vehicle studied. Analysis of variance showed

Average Percent Detection as a Function of Relative Location of Devices on Road for Each Type of Vehicle Studied

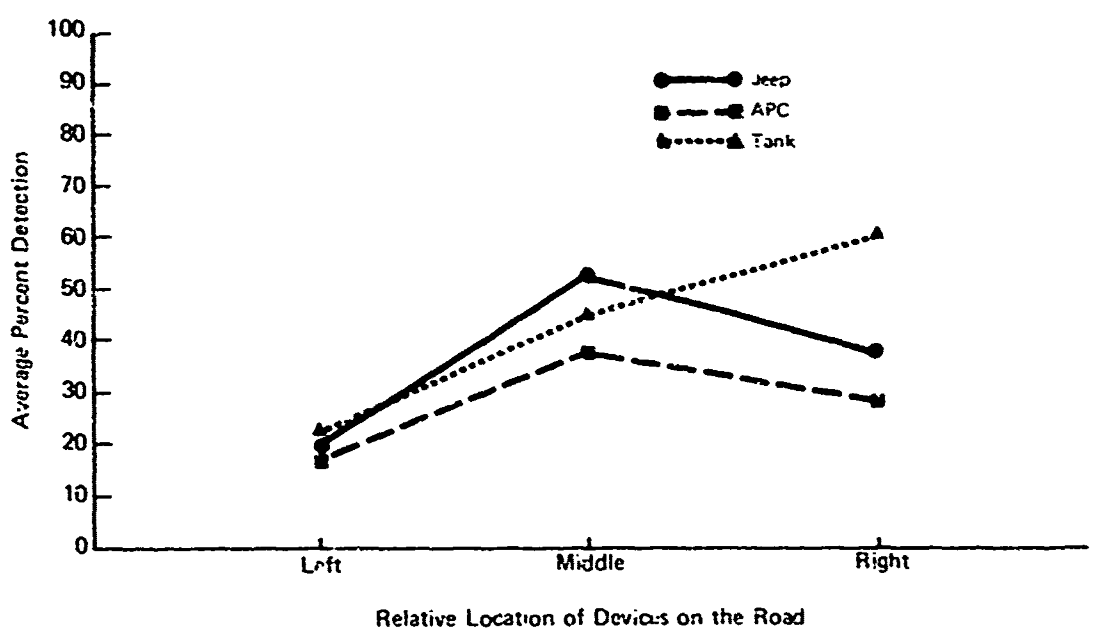


Figure 11

that the interaction between vehicle type and device location was significant ($F = 4.6$, $df = 4, 138$, $p < .01$). Also, the vehicle and location main effects were significant ($F = 13.6$, $df = 2, 69$, $p < .01$; and $F = 41.3$, $df = 2, 138$, p .01, respectively). Inspection of this interaction showed that (a) for both the jeep and APC, detection performance was higher for devices in the middle of the road, than for devices on either the left or right side of the road; and (b) for the tank, detection performance became progressively better as device location shifted from the left through the middle to the right side of the road. Thus, device location also was an important factor affecting the performance of the detection task in Course No. 1.

Analysis of variance of the percent detection for on-and-off road devices (Table XL) for both the 5 and 15 mph speeds revealed that only the vehicle main effects were significant. The significant vehicle main effects reflect the initial finding for this course: Jeep detection performance was best, APC detection performance second best, and tank detection performance least. The nonsignificant road location main effect indicated that the detection rates for on-road and off-road devices were not significantly different. This finding suggests that for the road course the off/on road device location was not a factor influencing device detection performance.

Table XL

Analysis of Variance of Detection Rate as a Function of the On-Road/Off-Road Device Location and Vehicular Type for 5 and 15 mph Speed

Speed	Source	df	MS	F	p
5 mph	Between Subjects				
	Vehicle (V)	2	1836.3	5.4	<.01
	Error (Subjects x Groups)	69	338.3		
	Within Subjects				
	On-Off road location (L)	1	39.1	<1	NS
	V x L	2	1155.4	1.8	NS
	Error (L x Subjects within groups)	69	640.9		
15 mph	Between Subjects				
	Vehicle (V)	2	2455.8	8.4	<.01
	Error (Subjects x Groups)	69	290.9		
	Within Subjects				
	On-Off road location (L)	1	212.7	<1	NS
	V x L	2	71.6	<1	NS
	Error (L x Subjects within groups)	69	326.9		

The average detection distance for each vehicle condition for on-road and off-road devices is presented in Table XLI. A t test for the differences between the on-road/off-road means for each vehicular condition showed that the differences were significant. Inspection of these t ratios indicated that the average detection distance for on-road devices was less than for off-road devices. This result suggests that visibility was an important factor in the detection of devices on the road since it was necessary for observers to get closer to the on-road devices than the off-road devices for detection to occur.

Table XLI

Average Detection Distance, Standard Deviation, and *t* Ratio for Each Vehicular Condition for On-Road and Off-Road Devices
(Meters)

	Type of Vehicle					
	Jeep		APC		Tank	
Device Location	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
On-Road	12.1	5.3	13.0	4.4	12.4	3.7
Off-Road	14.1	4.0	16.6	4.1	16.7	4.2
t	3.23		5.91		7.5	
df	348		284		204	

Human Factors Data Analysis—Course No. 2

Seventy-two men produced a total of 891 detections on Course No. 2. Of these, 890 (39.9%) were true detections, and one (0.1%) was a false detection. On this course each man had an opportunity to detect 32 devices. The average number of detections produced per man was 12.36 (SD = 5.2). The average detection rate was 38.6 percent (SD = 16.4%).

Testing for this course was also accomplished under three separate vehicular conditions (jeep, APC, and tank), with each condition being represented by 24 observers. Table XLII presents detection performance (average percent detected) for each of these conditions. Detection performance was best when the men observed from the tank, second best from the APC, and least from the jeep ($F = 9.09$, $df = 2, 69$, $p < .01$).

Table XLII

Average Percent Detected and Standard Deviation for Each Vehicular Condition Studied on Course No. 2

	Target Detection	
Type of Vehicle	$\bar{X}$	SD
Jeep	29.2	11.6
APC	39.4	14.9
Tank	47.3	17.2

Course No. 2 was laid out so that half the mines were on the left side of the test lane through the minefield, and half on the right side. Figure 12 presents the average detection performance for these two sections of the course for each vehicular condition.

Analysis of variance indicated that the interaction between vehicle condition and left/right device location was significant ($F = 3.79$, $df = 2, 69$, $p < .05$). For the jeep condition, average detection performance was better on the right half of the course than

Average Percent Detection for Each Vehicular Condition
as a Function of Course No. 2 Location

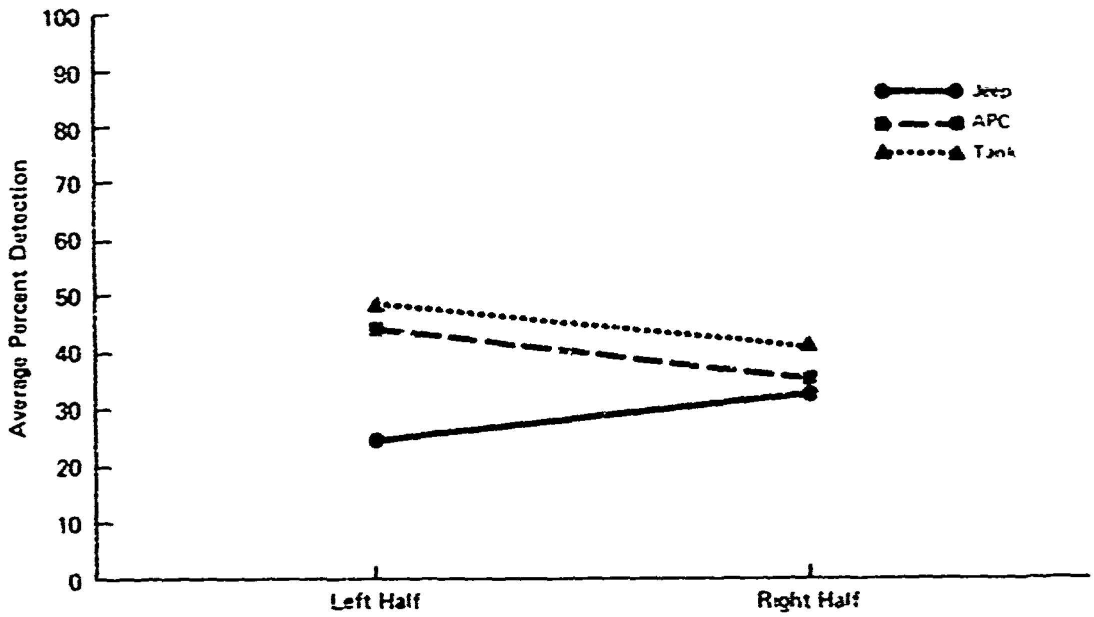


Figure 12

on the left half. The opposite was true for the APC and tank conditions. That is, average performance was better on the left half of the course than on the right half. This result indicates that device location and the type of vehicle from which the detection task is performed may interact to influence where, in an observer's field of view, detection proficiency will be highest.

Figure 13 presents the average detection performance for each vehicular condition as a function of observer-to-device range for both the left and right halves of Course No. 2. Analysis of variance of the data for the right half of the course indicated that the main effects of vehicle type and observer-to-device range were significant ($F = 4.88$, $df = 2, 69$, $p < .01$; and $F = 3.79$, $df = 3, 207$, $p < .01$, respectively) but that the interaction was not significant ($F = < 1$, $df = 6, 207$, NS).

For the right half of the course, for all vehicles (see Figure 13) as observer-to-device range increased, the average percent detection first showed a light increase from 2.5 meters to 7.5 meters and then a decrease from 7.5 meters on out. Analysis of variance of the data from the left half of the course also produced a significant vehicle type and observer-to-device main effects ($F = 10.63$, $df = 2, 69$, $p < .01$; $F = 20.52$, $df = 3, 207$, $p < .01$) as well as a significant interaction of the main effects ($F = 2.72$, $df = 6, 207$, $p < .05$). For the left half of the course (see Figure 13), the average detection rate showed a slight rise and then a drop for the jeep and APC conditions, while for the tank condition there was a drop and then a rise in the average detection rate as observer-to-device range increased.

These findings show that on Course No. 2 the observer-to-device range played a significant role in the detectability of devices. This finding reflects the fact that for an object of a given size, and as the distance from the object to the observer increases, its apparent size, and, hence, detectability decrease.

Average Percent Detection as a Function of Observer-to-Device Range for Left and Right Halves of Course No. 2

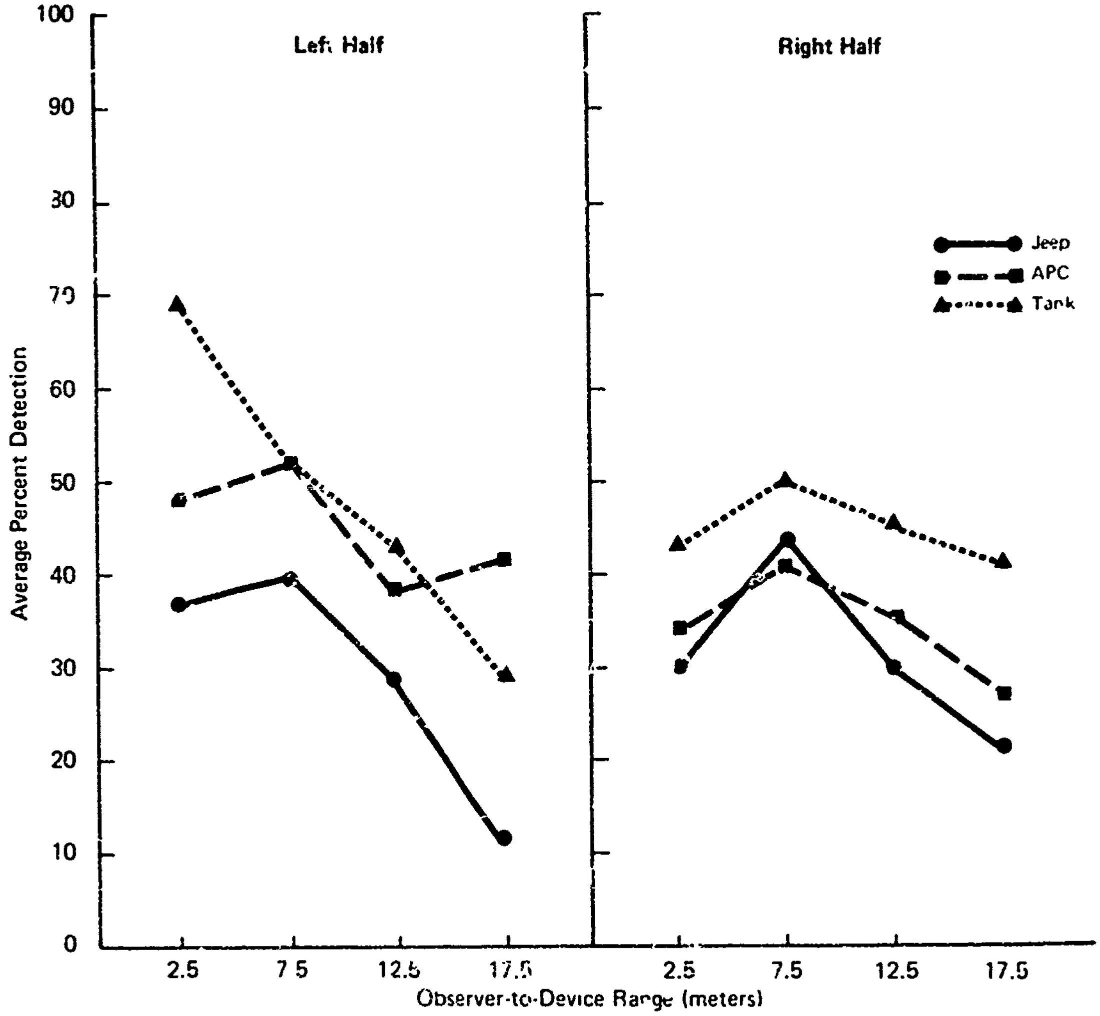


Figure 13

Human Factors Data Analysis—Course No. 3

Seventy-two men produced a total of 2282 detections on Course No. 3. Of these, 2274 (99.6%) were true detections, while the remaining 9 (.4%) were false detections. On this course each man had an opportunity to detect 90 devices. The average number detected per man was 31.6 devices (SD = 14.2). The average detection rate per man was 35.1 percent (SD = 15.8).

As was true for the other courses, testing was accomplished under three separate vehicular conditions (jeep, APC, and tank), with each condition being represented by observers. Table XLIII presents the detection performance (average percent detected) for each of these conditions. Detection performance was best when the men observed from the tank, second best when they observed from the APC, and lowest when they observed from the jeep ($F = 3.94$, $df = 2, 69$, $p < .05$).

Table XLIII

Average Percent Detected and Standard Deviation for Each Vehicular Condition Studied on Course No. 3

Type of Vehicle	Target Detection	
	$\bar{X}$	SD
Jeep	28.2	11.1
APC	36.8	13.9
Tank	40.3	19.3

is finding is reflected when the detection performance for the two sizes of mines employed in *Task F*—large (Teller and M15 with tilt rod) and small (POMZ and M16)—are considered separately. For each size of mine, detection performance was best when the test was completed from a tank, second best when completed from an APC, and lowest when completed from a jeep ($F = 4.2$, $df = 2, 69$, $p < .05$). Further, the larger devices were more detectable than the smaller devices ($F = 85.07$, $df = 1, 69$, $p < .01$). This was true for all vehicular conditions (see Figure 14).

Average Percent Detection for Each Vehicular Condition as a Function of Size of Course No. 3 Mines

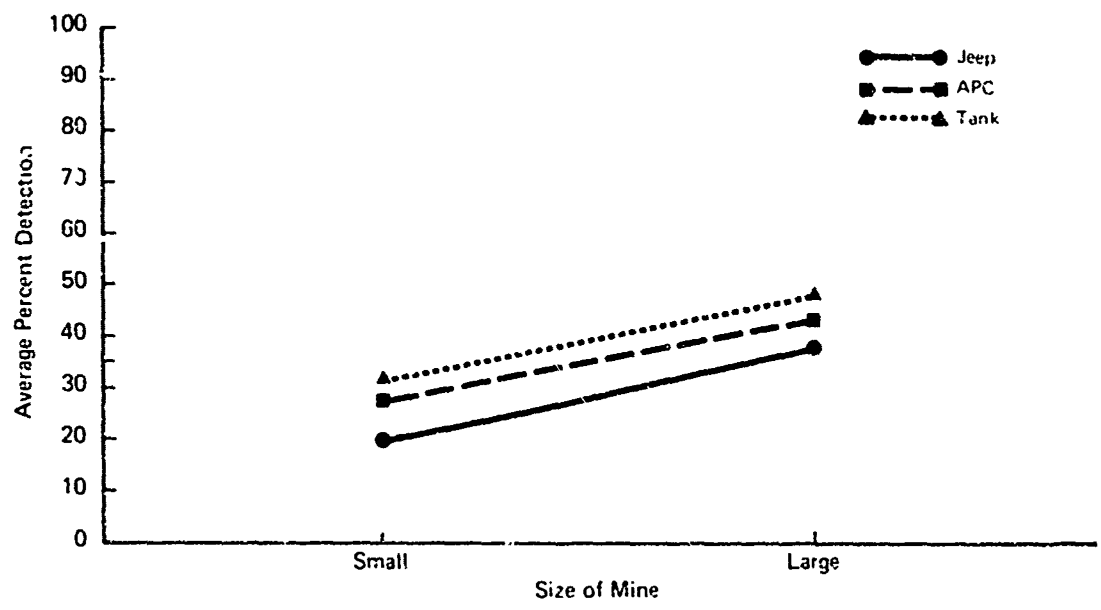


Figure 14

Course No. 3 was laid out in such a way that a little over half (57.8%) of the mines were to the left of the test lane, while the remainder (42.2%) were to the right of the test lane. Analysis of variance (see Table XLIV) indicated that, for both large mines (see

Table XLIV

Analysis of Variance of Detection Rate as a Function of the Left/Right Location and Vehicular Types for Large and Small Mines

Size of Mine	Source of Variance	*df*	MS	*f*	*p*
Large	Between Subjects				
	Vehicle (V)	2	1669.8	3.2	.05
	Error (Subjects x Groups)	69	525.0		
	Within Subjects				
	Left/Right Course Location (L)	1	2473.9	21.7	.01
	V x L	2	236.7	2.1	NS
	Error (L x Subjects Within Groups)	69	114.1		
Small	Between Subjects				
	Vehicle (V)	2	2445.6	4.4	.05
	Error (Subjects x Groups)	69	552.7		
	Within Subjects				
	Left/Right Course Location (L)	1	925.2	12.2	.01
	V x L	2	476.9	6.3	.01
	Error (L x Subjects Within Groups)	69	75.6		

Figure 15) and small mines (see Figure 16), the detection rate was generally higher on the right half of Course No. 3 than on the left half.

Figure 17 presents the average detection performance for large mines and Figure 18 for small mines, for each vehicular condition as a function of the observer-to-device range, for both the left and right halves of the course. *F* tests (see Table XLV) showed that for both halves of the course and for both large and small mines the effects of observer-to-device range were significant. This means that as the observer-to-device range increased, the average percent detections decreased for all vehicles. This result indicates that, as was true on Course No. 2, the observer-to-device range is an important factor influencing device detectability.

A plowed strip containing five buried mines was established within the main minefield to study detection performance under this condition. Knowledge of the detection of mines employed in this manner is important, since it is known that some foreign armed forces employ machines that implant mines in plowed furrows. Sixty-six (91.7%) of the observers detected one or more of the mines buried in the plowed strip. Analysis of variance indicated that the differences in the average percent detected among the three vehicular conditions were nonsignificant ($F = < 1$, $df = 2, 69$, NS). The average percent detected over all conditions was 60 percent (SD = 3.4). These results indicate that the detection of a plowed strip is not particularly difficult, but that detection of mines within the strip will average less than 100 percent.

Detection of the Beginning and End of the Course No. 2 and No. 3 Minefields

During the completion of Course No. 2 and No. 3, the observers were required to indicate (a) when they initially detected the forward edge of the minefield, and (b) when

Average Percent Detection for Each Vehicular Condition
as a Function of Course No. 3 Location for Large Mines

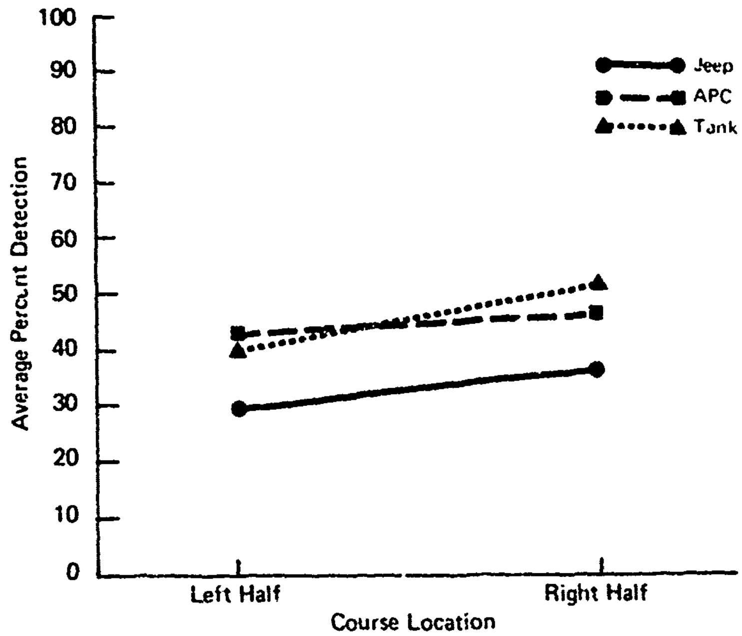


Figure 15

Average Percent Detection for Each Vehicular Condition
as a Function of Course No. 3 Location for Small Mines

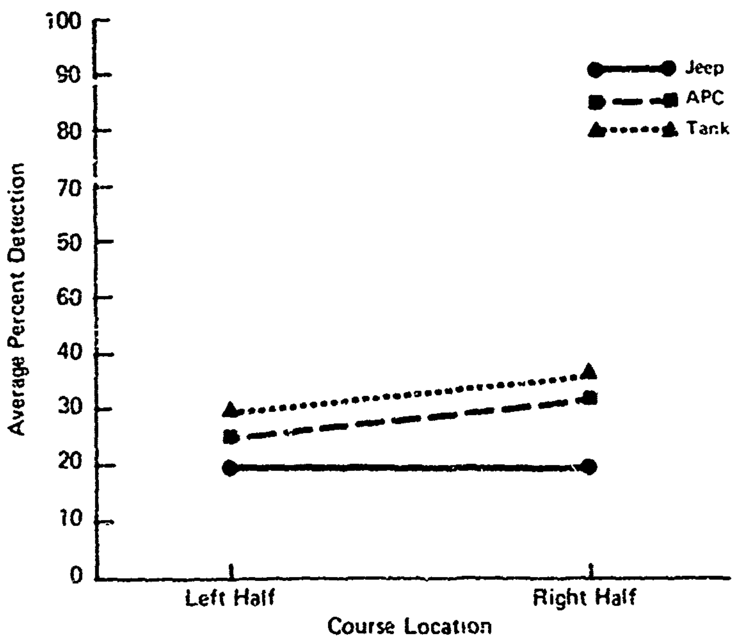


Figure 16

Average Percent Detection as a Function of Observer-to-Device Range for Left and Right Halves of Course No. 3 for Large Mines

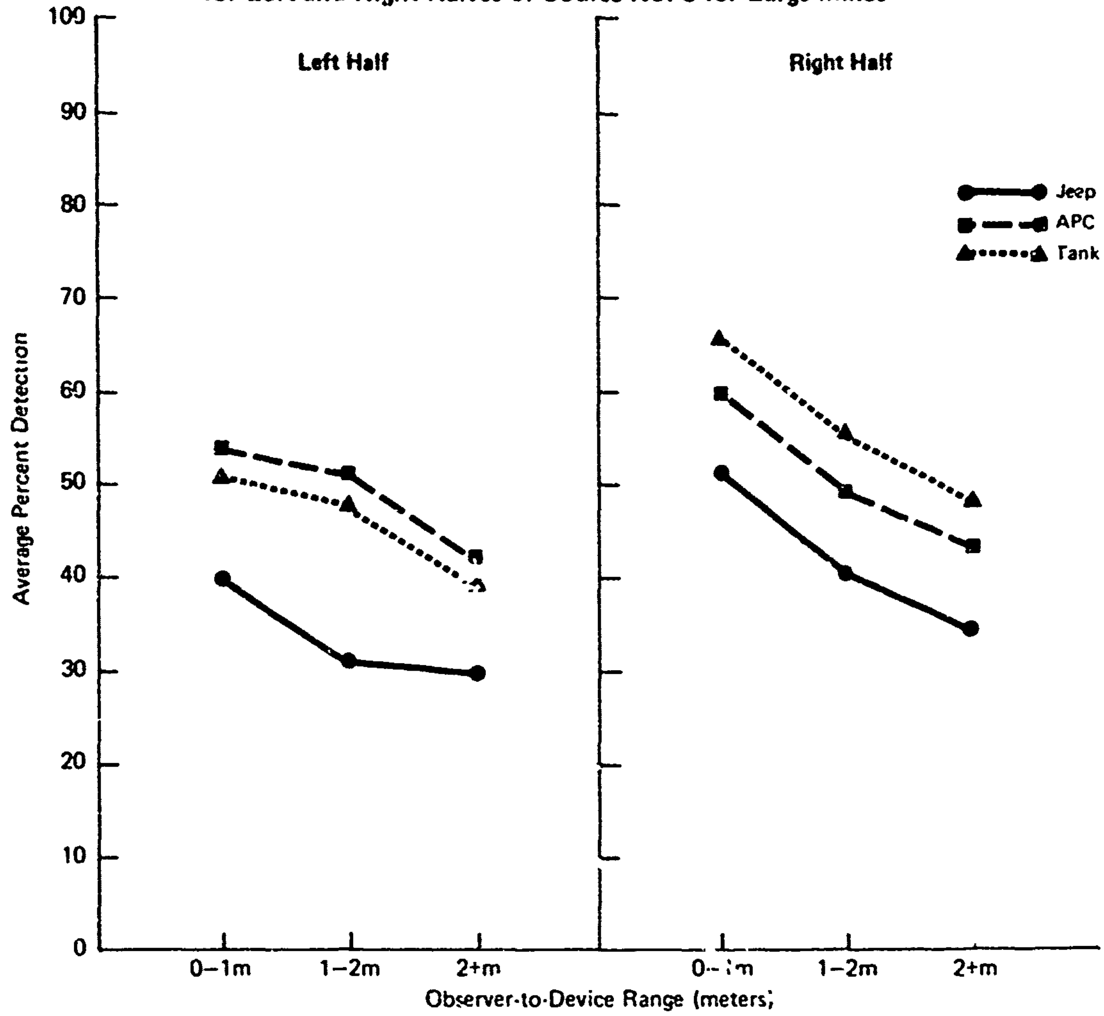


Figure 17

they thought they were out of the minefield. The location of the vehicle from which the men observed at the time these observations were made was then recorded on the score sheets.

For Course No. 2, 63 percent of the observers detected the forward edge of the minefield prior to entry, while for Course No. 3, 97 percent detected the forward edge prior to entering. Table XLVI presents the average distance of these observers from the forward edge at the time of detection for each vehicular condition. Analysis of variance indicated that for Course No. 2, the differences among vehicular conditions were not significant ($F = 1.64$, $df = 2, 42$, NS).

However, for Course No. 2, analysis of variance indicated that the differences among pre-entry detection distances were significant ($F = 10.74$, $df = 2, 67$, $p < .05$). A pairwise multiple comparison test showed that the difference between the mean pre-entry detection distance was not significant for the jeep and tank condition. However, the

Average Percent Detection as a Function of Observer-to-Device Range for Left and Right Halves of Course No. 3 for Small Mines

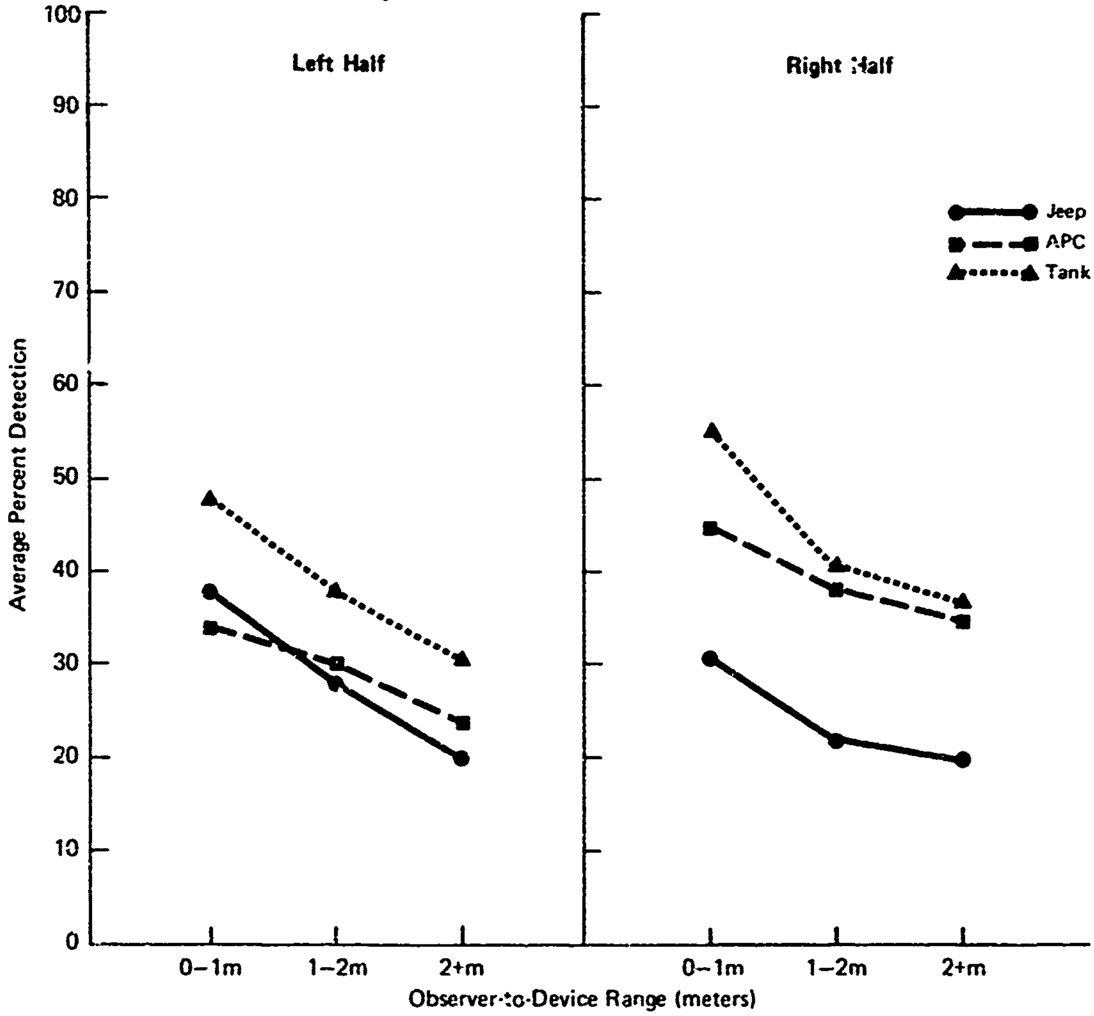


Figure 18

Table XLV

***F* Ratio for the Main Effect of Observer-to-Device Range for Large and Small Mines for Both Halves of Course No. 3**

Size of Mine	Half of the Course	*F*	*dfs*	*p*
Large	Right	113.03	2, 138	< .01
Large	Left	137.37	2, 138	< .01
Small	Right	62.27	2, 138	< .01
Small	Left	81.16	2, 138	< .01

Table XLVI

Average Distance From the Forward Edge of the Minefield at Detection From Each Vehicular Condition for Course No. 2 and No. 3

	Jeep			APC			Tank		
		Distance (meters)			Distance (meters)			Distance (meters)	
Course	N	$\bar{X}$	SD	N	$\bar{X}$	SD	N	$\bar{X}$	SD
No. 2	12	7.2	4.2	21	6.1	4.6	12	6.0	3.4
No. 3	24	13.6	3.7	22	6.2	4.5	24	10.2	6.2

differences between mean pre-entry distance for the jeep and APC, and for the tank and APC were found to be significant.

These results indicate that (a) the forward edge of the minefield on Course No. 2 was more difficult to detect than the forward edge of the minefield on Course No. 3, and (b) the type of vehicle from which the detection task was performed did not affect the magnitude of the pre-entry detection distance on Course No. 2, while it did on Course No. 3.

Finally, it was found that none of the observers in the study was able to detect the end of the minefield on Course No. 2, and only 5.5 percent were able to detect the end of the minefield on Course No. 3 prior to actually leaving the course. This result indicates that the detection of the end of a minefield prior to exiting is a much more difficult task than detecting the beginning of a minefield before entering it.

Relationship of Effort Ratings to Detection Performance

During the completion of each detection course, the evaluator observed the effort the subjects appeared to expend. Each man was rated four times by an evaluator, using a five-point scale: once each after the completion of Part A and Part B of Course No. 1, once after the completion of Course No. 2, and once after the completion of Course No. 3. These ratings were then averaged to obtain an overall effort rating for all test courses. In addition, for each observer a total detection score (average percentage of detections) was calculated by averaging the percentage of detections obtained on each test course. These two scores were then correlated with each other to determine for each vehicular condition the predictability of the total detection score from knowledge of the level of effort score. These correlations are presented in Table XLVII. All were significant

Table XLVII

Relationship of Effort Ratings to Average Detection Performance

Type of Vehicle From Which the Detection Was Performed	Correlation	*df*	*p*
Jeep	.56	22	$< .01$
APC	.66	22	$< .01$
Tank	.75	22	$< .01$

at the .01 level and were from moderate to high in magnitude. This finding indicates that the level of effort observers manifested during testing was predictive of their average detection performance.

In addition, it can be observed that the magnitude of the correlation between average effort and average detection performance appeared to improve as a function of the order in which the data were collected during the study. The study was run so that jeep data were collected first, the APC data next, and the tank data last. Inspection of Table XLVII indicates that the magnitude of the effort-detection correlation increased from jeep condition to the tank condition. This result suggests that the evaluators may have improved in their proficiency at making effort evaluations as the study progressed. Under these conditions, it would be expected that any true relationship between effort and detection would improve due to the improved reliability in the effort ratings.

Chapter 4

TASK G: POTENTIAL CHARACTERISTICS, ATTITUDES, AND ACQUIRED SKILLS IN MINE DETECTION

BACKGROUND

The purpose of *Task G* was to present the results of an additional analysis of data from previously reported studies. A more complete description of that research (*Tasks A* and *B*) is contained in HumRRO Technical Report 73-18.[1]

Basically, the previous work was focused on identifying appropriate selection and training methods for human mine and boobytrap detection. In the completion of work related to that purpose, a substantial number of possible predictor measures were identified, each of which had some promise for predicting mine and boobytrap detection performance. A field mine and boobytrap detection course was constructed, to serve as a criterion of detection performance. The predictor measures were validated against the criterion of performance effectiveness through the use of stepwise regression procedures. The multiple correlation obtained through the stepwise procedure proved to be highly significant, reaching .74 in the fourth step which was significant beyond the .01 level of confidence.

The predictor variables entering the first four steps were: (a) time taken during search, (b) apparent effort expended during search (an evaluator rating), (c) civilian education completed, and (d) activities participation index. The first three are self-explanatory. The fourth is a measure of the number of adventuresome activities in which the test subject had participated, one component of a HumRRO test from which it is possible to derive an apparent measure of general and specific confidence of the individual in his ability to overcome challenging situations (see Appendix A).

Following the report on the results of this study, a briefing at U.S. Army Materiel Command (USAMC) Headquarters led to several questions concerning reliability of individual scores, equivalence of scores obtained on different mine and boobytrap lanes, equivalence of task posed by various devices used, and theoretical significance of the predictors found to be related to field performance. The focus was primarily on the question of the reliability of detection performance scores obtained from individual pairs of lanes, and on the wisdom of combining scores (numbers of detections for each of a variety of devices) into one total score to indicate performance

To review, eight different mine and boobytrap detection lanes of 400 meters each were developed for the first, and major, part of the test of field performance effectiveness. Subjects were soldiers from the 197th Infantry Brigade at Fort Benning, available during the period of 12 March-5 April 1973. At the test site, subjects proceeded individually through the lanes, observed and controlled by an experimenter. The course traversed by an individual subject consisted of one pair of lanes, out of the total of four possible pairs. The procedure required him to move outbound on an odd-numbered lane, and return on an even-numbered lane. Thus, the total sample of subjects was tested on what amounted to four parallel forms of the same test. Each of these parallel forms was

[1] Maxey, *et al.*, *op. cit.*, August 1973.

constructed according to the same rigorous guidelines for lane construction. A daily check was made on detection rates for device types from one lane to another, to ensure that the lanes were of comparable difficulty.

However, even with these precautions, it is conceptually possible still to question whether the lanes were, in fact, parallel forms. Also, it is conceptually possible to question whether the detection of an above-surface device relies on the same basic aptitudes and skills as detection of subsurface devices. The *Task G* analyses were designed to answer these questions.

APPROACH TO THE PROBLEM

Seven different types of devices were available for detection. Course I (the mine and boobytrap course) had eight different lanes, with each subject tested on two of the eight lanes. A record was maintained not only of each subject's search time and rated effort, but also of the devices he detected on the two lanes he traversed. These data permitted the accomplishment of several reliability analyses.

In the first analysis, a separate score was obtained for each subject, for each kind of device available for detection, for each lane. The resulting score matrix for each device type, then, consisted of 26 subjects each, with two exposures each, that is, one for odd lanes and one for even lanes (1 and 2, 3 and 4, 5 and 6, 7 and 8). An odd-even reliability analysis was conducted by correlating the subject's detections of each type of device on the odd-numbered lanes with his detections of the same type of device for even-numbered lanes. This analysis was designed to determine the extent to which the soldier's performance on one lane was the same as his performance on the other. That finding would lead to the conclusion that alternate lanes posed generally equivalent requirements, and would permit the inference that the lane construction guidelines were effective in producing parallel forms of the same test, and that all lanes probably were also equivalent. As an additional step, the same type of reliability analysis was performed for total detections, that is, the sums of the detections of the seven individual types of devices.

Construct validity analyses were also undertaken. As noted, it is possible to question whether the skill requirements posed for one type of device are the same as those posed for another. At least two reasons exist for raising this question: (a) The detection tasks do appear to be conceptually different, and perhaps to require different search techniques; (b) Bucklin's studies with surface-laid munitions yielded somewhat different correlations with predictors than the HumRRO study with different types of munitions.

In the first type of construct validity study, the total number of detections obtained by each subject for each type of device was correlated with the total number of detections by that subject for each other type of device. If the skills required for device detection are specific to the device, the correlations between similar device types should have been higher than the correlations between different device types. In order to investigate these questions, two factor analyses on the predictor and criterion data were performed.

As a second approach to investigating construct validity, the total number of detections for each individual type of device was subjected to the same stepwise multiple regression procedure used for total detections in the previous HumRRO study. This led to a multiple correlation for each type of device, as opposed to total detections. This analysis was designed to permit a determination not only of whether different aptitudes enter into the detection skills for the various devices, but also whether some types of devices are essentially more predictable than other types.

Finally, a factor analysis was performed on the matrix of intercorrelations of the variables used in the previous *Task B* study. In addition, a new matrix was developed

which contained individual device detection scores and a factor analysis was performed on that matrix as well.

RESULTS

Reliability Analyses

The primary results of the reliability analyses are shown in Table XLVIII. The first four columns show odd-even correlations for the four adjacent pairs of lanes constituting the course; one-fourth of the subjects were tested on each of the four adjacent pairs.

Table XLVIII

Odd/Even Lane Correlations for Individual Devices

Device	Lanes[a]				Total Odd/Even Over All Lanes and Subjects (N=104)[b]
	1 & 2 (N=26)	3 & 4 (N=26)	5 & 6 (N=26)	7 & 8 (N=26)	
M25 APM	.47	.35	.04	.38	.34
M16 APM	.35	.36	.22	.26	.25
Schumine	.31	.37	.43	.56	.33
Grenade tripwire	.30	.49	.12	.42	.32
Claymore	.14	.49	.30	.39	.27
105mm round	.39	.52	.24	.25	.26
DH10 (Russian Claymore)	-.09	.00[c]	.06	.30	.08
Total	.62	.79	.53	.61	.63
Total corrected[d]	.77	.88	.69	.76	.77

[a]For N = 26, a correlation of .39 or higher (positive or negative) was significant, $p < .05$; or higher, $p < .01$.

[b]For N = 104, a correlation of .19 or higher was significant, $p < .05$, .25, $p < .01$.

[c]On one lane, all DH10 devices were detected by all subjects. The variance on this lane therefore was zero, and the correlation also had to be zero.

[d]Reflects application of Spearman-Brown formula to estimate reliability of a total based on correlation of two halves of the total

Examination of the correlations shows several interesting findings. First, the frequencies with which individual device types were detected across odd and even lanes were not highly correlated. Most of the correlations for specific device types ranged from approximately .2 to approximately .5, with the exception of the correlations involving the DH10. Those correlations were generally quite low, and unacceptably so (A check of the raw scores provided the explanation. There were very few failures to detect the DH10 devices. Thus, the variance was low—less than 25 percent of the size of the next lowest variance—and the correlations involving DH10 devices had to be low as a consequence.)

The fact that the individual device reliabilities were as low as they were suggests that caution must be exercised in their use. This does not prohibit the use of group means for individual devices in order to estimate probability of detection under the conditions of this experiment. However, the reliability of a single individual's score is probably too low for all but the most cautious further use. This, of course, applies particularly to frequency of detection of the DH10.

Where total scores were concerned, however, the findings do not imply a need for such caution. The next-to-last row of Table XLVIII shows correlations between a subject's total score for the odd lane of a pair, and his total score for the even lane of that pair. With one exception, these correlations are all of very acceptable magnitude. All are significant beyond the .01 level of confidence, and four of the five exceed .6. The last row of the table shows the results of applying the Spearman-Brown General Prophecy Formula to estimate the reliability of each subject's total score, based on the correlation between the two halves of the total. As can be seen, the lowest is .69 while the highest is .88. The conventional lower limit of acceptability for reliability of a test, where that test is to be used to measure individual performance, is .70. Thus, even the worst of the five pairs of lanes yielded a reliability quite close to that level of magnitude, while the remaining four exceeded it. This suggests that the reliability of total scores was quite adequate for the purpose for which they were used in the previous study, that is, as a criterion of mine and boobytrap detection performance in order to validate possible predictors of that performance skill.

Construct Validity Analyses

Two kinds of construct validity analyses were conducted. The first consisted of two factor analyses of a matrix of intercorrelations from the variables of the preceding study. The second consisted of stepwise multiple regression analyses.

Factor Analyses. The first factor analysis is shown in Table XLIX; the input variables consisted of the battery of predictor scores, together with total detections. The factor analysis model was a principal components solution with a varimax rotation.

Table XLIX

Factor Analysis of Predictor Variables and Major Criterion Variable (Total Number of Detections) Studied in Project IDENTIFY

	Factor				
Variable[a]	I	II	III	IV	V
Race	-.61	.13	.13	-.17	.12
Information Extraction	.60	.10	-.02	.01	-.07
Embedded Figures	.52	.18	-.10	.16	.04
Total Knowledge Score	.45	.10	.09	.05	-.06
Incomplete Objects	.44	-.01	.15	.01	.06
Manifest Anxiety	-.41	-.10	.09	.06	-.20
Search Time	.08	.72	-.05	-.06	-.10
Effort Expended in Search	.13	.64	-.06	.02	.01
Total Detection	.10	.79	.04	-.00	.15
Height	.01	.07	.68	.11	.05
Weight	-.08	-.04	.63	.04	.10
Confidence Index	.45	.14	.14	.60	.08
Despair Index	.15	.04	.09	.75	.17
Age	-.14	.01	.01	.05	.44
Visual Acuity	-.08	.08	-.01	.11	-.41
Team Orientation	.13	.05	.04	.14	.40

[a]Unless a variable loaded at least as high as .40 on at least one factor, it was omitted from the listing

Five meaningful factors emerged from this analysis, and are shown in Table XLIX. (Variables which did not load above .4 on at least one factor were excluded from this table.) Examination of this table showed several interesting results.

Factor I, defined by the first six variables in the table, consisted of test-taking skills. That is, with the exception of race, the five remaining variables which defined the factor were paper-and-pencil test measures. Significantly, the criterion—total number of detections—did not load on this factor and the test measures did not load on Factor II, which contained the criterion. The suggestion is that paper-and-pencil test measures depended on performance skills which were simply different from those required to detect mines and boobytraps.

Factor II was defined by three variables: the criterion, search time, and effort. Both search time and effort were highly correlated with the total number of detections. Interestingly, no other variable in the table loaded on this factor, and these variables themselves did not load on any other factor.

Factor III was defined by height and weight, two physical variables which appeared not to be related to any other factor and which were not related to detection proficiency.

Factor IV was defined by two measures from one test, which purports to measure the individual's confidence in his ability to perform activities that are adventuresome and challenging. The confidence index also loaded on the test-taking factor.

Finally, Factor V was essentially a miscellaneous one defined by age, visual acuity, and team task motivation. While the three loadings were greater than or equal to .40, this factor was not thought to be particularly meaningful.

The most striking observation from the table is that the criterion measure, together with search time and effort, constituted a relatively independent factor, not related to the paper-and-pencil measures. This suggests that previously obtained correlations of paper-and-pencil measures with mine and boobytrap detection performance may essentially be spurious.

These factor analysis results gave ample evidence of the lack of relationship between the paper-and-pencil predictor tests and detection performance. Given that general finding, it seemed useful to perform one additional factor-analytic study of the data, to determine whether the individual types of devices themselves would all load on the same factor. It appeared entirely possible that they might not, and that such a study would provide insights into possible differential abilities required for detection of different type devices.

The results of the principal components factor analysis with varimax rotation are shown in Table L. The factor structure is similar to the preceding one, but with some significant differences. The first factor in Table L is a detection skills factor. This factor probably emerged first, instead of the test-taking factor, because of the inclusion of individual scores for the various devices detected. In this table, loadings of .50 and above are enclosed with a solid box to facilitate identification, and loadings of .40 to .49, inclusive, are enclosed in dashed boxes.

Examination of the loadings for Factor I showed the total score loading heavily on this factor, together with time and effort. Interestingly, detections for the M25, the M16, and the Schumine also loaded strongly on this factor. Interestingly, too, the remaining devices loaded considerably less strongly, suggesting that, at least to some extent, the underlying skills involved in detecting them are different from the first three devices listed, which are all *subsurface* devices.

The second factor was a test-taking factor, essentially the same as the one described for the preceding factor analysis.

Factor III gains meaning, however, from the inclusion of individual device detection scores. As before, the highest loadings are height and weight. These two

Table L

Factor Analysis of All Predictor and Criterion Variables Studied in Project IDENTIFY

	Variable	Factor				
		I	II	III	IV	V
		Detection	Test Taking	Size/Above-Ground Devices	Confidence/Despair	Group Orientation
1.	Age	-.01	-.18	.05	.08	.63
2.	Height	.01	.03	.73	.13	.10
3.	Weight	-.13	-.06	.64	.05	.22
4.	Civilian Education	.29	-.19	.09	-.34	.41
5.	Visual Acuity	.03	-.06	-.01	.16	-.55
6.	Years of Smoking	-.05	.03	-.11	.57	.01
7.	Dogmatism (Opinions)	-.06	-.29	-.11	.47	-.24
8.	Manifest Anxiety	-.10	-.49	.22	.10	-.29
9.	Team Orientation (Motivation)	.08	.12	.09	.19	.55
10.	Total Knowledge Score	.07	.58	.15	-.01	-.09
11.	Embedded Figures	.19	.56	-.12	.22	.03
12.	Information Extraction	.10	.66	-.00	-.04	-.13
13.	Incomplete Objects	-.06	.56	.06	-.04	.17
14.	Background Confidence	.15	.51	.25	.54	.06
15.	Background Despair	.08	.18	.25	.74	.12
16.	Course I Search Time	.74	.07	.01	-.08	-.18
17.	Race	.11	-.68	.10	-.16	-.14
18.	Effort Expended in Search	.66	.16	.09	-.04	-.05
19.	Search Technique	-.10	.10	.37	-.25	-.07
20.	M25 Detections	.70	-.04	-.15	.06	.07
21.	M16 Detections	.70	.01	-.22	.18	.23
22.	Schumine	.69	.08	-.19	.18	.06
23.	Grenade Tripwire	.40	.29	.17	.27	.12
24.	Claymore	.50	-.01	.42	-.25	-.00
25.	105mm Round	.52	.02	.43	-.15	.02
26.	DH10	.40	-.20	.41	.04	-.21
27.	Total Detection	.95	.09	.09	-.04	.13

variables define the factor. However, the Claymore, the 105mm round, and the DH10 all load higher than .40 on this factor. Further, search technique (Variable 19) loads .37 on this factor—higher on this than on any other single factor. Its low loading probably reflects low variance in search scores. However, this factor might be interpreted as suggesting that search technique may be related to an individual's size (probably his height), and that it may be associated with detection of above-ground devices to a considerably greater extent than for subsurface devices. Further, the tendency of the Claymore, the 105, and the DH10 to load on this factor confirmed that detection of these devices probably depended, at least to some extent, on a somewhat more complex search technique than the subsurface devices.

The remaining two factors were quite similar to Factors IV and V identified in the previous analysis, except that two additional variables load on Factor IV.

Some substantiation of the partial independence of device types is gained from examination of Table LI, which identifies the major detection clue reported by subjects at the time of device detection. Color, texture, and shape generally were dominant clues. However, the number of detection clues reported differed from one type of device to another, conditioned in part by different detection frequencies and by different numbers of devices to be detected in the course.

Table LI

Number of Times Each Detection Clue Was Reported Used on Course I

Detection Clue[a]	M25	M16	Schumine	Hand Grenade Tripwire	Claymore	105mm Round	DH10
Color	137	151	195	92	121	91	56
Camouflage	8	28	29	4	22	15	22
Vegetation	0	0	3	0	0	0	1
Soil	0	0	0	0	0	0	0
Size	0	0	0	0	7	27	11
Shape	12	34	33	10	65	149	96
Texture	118	123	72	227	45	26	11
Total	275	336	332	333	260	308	197

[a]For some devices, multiple clues were reported for detection (e.g., a Schumine detection may have been based on variation in both color and camouflage).

Table LII shows each of the raw frequencies of Table LI converted into a percentage. Examination of this table shows strong confirmation for the findings derived from examination of the second factor analysis. Color was the dominant clue for the M25, the M16, and the Schumine. It was also the dominant clue for the Claymore. While occurring in significant frequency for each of the remaining three devices, it was less dominant as a clue than shape (for the 105mm round and the DH10) and texture (for the hand grenade tripwire). Texture was a strong secondary clue for the M25 and the M16, and a moderately strong clue for the Schumine.

Taken together with the results of the second factor analysis, it is quite interesting that the three devices for which shape was an important detection clue are the same three devices which loaded on Factor III. By the same token, the three devices loading most highly on Factor I were characterized by a predominance of color clues,

Table LII

Percent of Report of Detection Clue by Device on Course I

Detection Clue	M25	M16	Schumine	Hand Grenade Tripwire	Claymore	105mm Round	DH10
Color	50	45	59	28	47	30	28
Camouflage	3	8	9	1	8	5	11
Vegetation	0	0	1	0	0	0	1
Soil	0	0	0	0	0	0	0
Size	0	0	0	0	3	9	6
Shape	4	10	10	3	25	48	49
Texture	43	37	22	68	17	8	6

followed by a relatively strong secondary contribution of texture clues. These results again strongly suggest the operation of two different kinds of processes.

Tables LIII and LIV show a similar breakout of errors in placement reported by device. Inadequate camouflage was the predominant clue for all devices except the hand grenade tripwire, for which exposure of the triggering device was the predominant error. It should be noted also that a substantial number of subjects reported anticipating a detection as a consequence of "tactical conditions."

While examination of errors in placement is of interest in itself, systematic variations between devices of the sort found in Tables LI and LII are not apparent.

One final bit of evidence confirming that different detection tasks were presented by the different detection devices is shown in Table LV. In the matrix of

Table LIII

Number of Errors in Placement Leading to Detection

Errors in Placement	M25	M16	Schumine	Hand Grenade Tripwire	Claymore	105mm Round	DH10
Inadequate Camouflage	17	28	31	4	32	28	20
Failure to Renew Camouflage	0	1	0	0	0	0	0
Continued Use of Same Technique	0	0	0	0	0	0	0
Disturbed Soil	0	0	1	0	0	0	0
Disturbed Vegetation	1	9	4	0	0	2	1
M/BT Exposed	0	5	3	26	2	1	1
Tripping Device Exposed	2	27	1	448	0	4	1
Anticipated by Tactical Conditions	8	18	10	15	17	6	8
Total	28	88	50	493	51	41	31

Table LIV

Percent of Errors in Placement Leading to Detection

Errors in Placement	M25	M16	Schumine	Hand Grenade Tripwire	Claymore	105mm Round	DH10
Inadequate Cover	61	32	62	1	63	68	65
Failure to Renew Cover	0	1	0	0	0	0	0
Continued Use of Same Technique	0	0	0	0	0	0	0
Disturbed Soil	0	0	2	0	0	0	0
Disturbed Vegetation	4	10	8	0	0	5	3
M/BT Exposed	0	6	6	5	4	2	3
Triggering Device Exposed	7	31	2	91	0	10	3
Anticipated by Tactical Conditions	29	20	20	3	33	15	26

intercorrelations shown there, each subject's scores for each type of device, together with the total, are included in three ways: his score on the odd-numbered lane, his score on the even-numbered lane, and his total score combining both lanes. Sets of lines have been included in the matrix to make it easier to identify salient elements.

The principal observation to be made from the matrix is that correlations are higher among clusters formed by M25s, M16s, and Schumines, on the one hand, and Claymores, 105mm rounds, and DH10s, on the other hand. Conversely, correlations among these types of devices and device types outside their clusters tend to be lower. Four sets of clusters may be inspected in the table for this observation. Three fall along the diagonal of the matrix, and consist of triangular subsets of correlations, each of which contains two smaller triangles with three contained correlations. Starting from the upper left, the first major subset contains correlations among devices on odd lanes only. The second subset contains intercorrelations among devices in even lanes only. Finally, the third subset contains total scores, with odd and even lanes combined.

The primary exception to the tendency for correlations within the small triangles to be larger than those outside them occurs in the case of the DH10 on even-numbered lanes. As was explained earlier, the number of failures to detect was so small that correlations with the DH10 were virtually eliminated.

The final subset of correlations appears in the rectangle outlined below the diagonal of the table, containing correlations between devices in even lanes and their counterparts in odd lanes. Again, there is a substantial tendency for correlations within the two clusters to be higher than correlations outside the clusters, with the exception of those involving the DH10.

Stepwise Multiple Regression Analyses. Given that different underlying skills appeared to be accounting for detections in the cluster of subsurface devices as opposed to above-surface devices, stepwise multiple correlations were run for individual device detections, paralleling the stepwise regression obtained on total scores and reported in the previous report. It was expected at the outset that different primary predictors might emerge for the different devices. Table LVI contains a summary of the stepwise multiple

Table LV

Odd-Even and Total Correlations: First Field Study

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1 O M25	.																							
2 O M16	.33																							
3 O Schumine	.27	.34																						
4 O Granade TW	.05	11	-.12	.																				
5 O Claymore	05	16	23	.01	.																			
6 O 105mm Round	.21	.21	.23	.23	.33	.																		
7 O DH10	07	.01	.11	12	.28	38	.																	
8 O Total Det.	.58	68	.59	38	.49	.62	.35	..																
9 E M25	.34	.38	.40	.13	.18	.20	.16	.50	..															
10 E M16	34	.25	.25	-.02	.20	-.06	.03	.30	.29	..														
11 E Schumine	.24	.36	.33	.10	.16	.24	.03	.42	.34	.32	.													
12 E Granade TW	12	.05	.20	.32	22	.16	.14	.32	.16	.22	+.16	.												
13 E Claymore	.01	.01	.08	.22	.27	17	.28	.22	.09	.05	19	.11	..											
14 E 105mm Round	-05	09	.22	.03	.42	.26	.04	.27	.14	.18	.10	.15	.36	..										
15 E DH10	10	02	.02	.05	.22	.02	.08	.12	.09	-.06	.08	-04	.16	.02	..									
16 E Total Det.	36	.36	45	22	.42	.27	19	.63	.63	.56	.58	.58	.33	.48	.15	..								
17 M25	81	[illegible]	.41	11	.14	.25	14	.66	.82	.39	.35	.17	.05	11	.11	.61	..							
18 M16	43	79	.37	.06	.23	10	.02	63	.42	.79	.44	.17	.02	.17	.02	.65	.52	..						
19 Schumine	31	44	82	-02	24	.29	.09	62	.45	.35	.81	.22	-.07	.20	.06	.63	.47	.50	..					
20 Grenade TW	11	10	.06	78	15	.24	.16	.43	.18	.13	.16	.84	.20	.08	.00	.51	.17	.14	.14	..				
21 Claymore	03	10	.20	14	.81	.32	.35	.45	.17	.16	.02	.21	.78	.49	.24	.47	.12	.16	.12	.22	..			
22 105mm Round	16	.19	.29	.13	.47	.81	.27	.56	.22	.07	.22	.20	.33	.78	.03	.47	.23	.17	.31	.20	.51	..		
23 DH10	11	.02	10	.12	.35	30	.79	.33	.18	-.01	.07	.08	.30	.04	.67	.23	.17	.00	.10	.12	.41	.22	..	
24 Total Det	.52	.58	58	.33	.50	.49	30	.90	.63	.53	.55	.50	.31	.42	.15	.90	.70	.70	.69	.52	.51	.57	.32	..

Table LVI

Stepwise Multiple Correlations for Individual Device Detections and Total Scores

Device	Variable	Regression Coefficient (B)	Simple Correlation (r)	Multiple Correlation (R)	F-Ratio
M-25	1. Course I Search Time	.46	.47	.47	28.41
	2. GED Tests Completed	-.23	-.17	.50	16.56
	3. Frequency of Activities	.16	.09	.52	12.09
	4. Knowledge of Mine Fields	-.15	-.16	.54	9.93
	5. High School Graduation	.18	.09	.55	8.67
	6. Age	-.12	-.11	.57	7.62
M16	1. Effort Expended in Search	.30	.41	.41	20.37
	2. Civilian Education Completed	.26	.28	.47	14.38
	3. Years of Smoking	21	.12	.52	12.16
	4. Course I Search Time	.24	.40	.56	11.11
	5. Knowledge of Detection Means	.17	.18	.57	9.52
	6. Knowledge of Mines and Boobytraps	-.14	.00	.59	8.46
Schumine	1. Course I Search Time	.30	.43	.44	23.79
	2. Effort Expended in Search	.24	.39	.48	15.12
	3. Embedded Figures	09	.20	.49	10.58
	4. Visual Acuity	-09	-.05	.50	8.20
	5. Years of Smoking	.08	.07	.50	6.71
	6. Weight	-.07	-.11	.51	5.67
Grenade	1. Effort Expended in Search	.24	.37	.37	16.62
	2 Manifest Anxiety	-22	30	.45	12.70
	3. Course I Search Time	.18	32	.47	9.53
	4. Weight	.14	.12	.49	7.95
	5. Incomplete Objects	11	.17	.51	6.77
	6. Civilian Education Completed	.09	.14	.51	5.83
Claymore	1. Course I Search Time	.23	.35	.35	14.45
	2. High School Graduation	.15	.31	.45	13.15
	3. Effort Expended in Search	.24	.35	.50	11.08
	4 Manifest Anxiety	.16	.10	.52	9 00
	5. Dogmatism (Opinions)	-.14	-.17	.54	7.87
	6. Civilian Education Completed	.16	33	.55	7.01
105mm	1. Course I Search Time	.25	.30	.30	9.90
	2. Civilian Education Completed	.19	.24	.36	7.55
	3. Height	.20	.19	.41	6.71
	4. Knowledge of Mines and Boobytraps	14	.18	.44	5.93
	5. Years of Smoking	-19	-19	.47	5.44
	6. Frequency of Activities	16	.13	.49	5.12
[illegible]H10	1. Course I Search Time	29	35	.35	14.17
	2. Height	19	20	40	9.67
	3. Incomplete Objects	-19	-19	.44	8.13
	4. Effort Expended in Search	15	.28	.46	6.74
	5. Knowledge of Mines and Boobytraps	12	-07	.48	5.76
	6. Background Despair	08	.09	.48	4.92

(Continued)

Table LVI *(Continued)*

Stepwise Multiple Correlations for Individual Device Detections and Total Scores

Device	Variable	Regression Coefficient (B)	Simple Correlation (*r*)	Multiple Correlation (*R*)	*F*-Ratio
Total	1. Course I Search Time	.46	.62	.62	64.04
	2. Effort Expended in Search	.32	.57	.69	47.52
	3. Civilian Education Completed	.20	.28	.72	36.67
	4. Frequency of Activities	.16	.14	.74	29.84
	5. Dogmatism (Opinions)	-.09	-.14	.75	24.87
	6. Visual Acuity	-.09	-.07	.75	21.12

regression analyses for each of the individual devices. All analyses were terminated at Step 6.

Examination of the summaries for each of the individual devices showed a rather disappointing pattern. As might be expected from the relatively lower reliabilities of the individual device detection scores (as opposed to total score), the primary contribution to the multiple was obtained from the first two variables, and sometimes three. In all cases, either time or rated effort emerged as the primary predictor of device detection frequency. This finding suggests that if different underlying abilities are responsible for detection of subsurface and above-surface devices, the prediction battery assembled for the previously reported study did not contain instruments for measuring them.

Chapter 5

DISCUSSION

PREDICTION OF DETECTION PERFORMANCE

Correlations between the individual differences assessed during testing and detection proficiency for the film and field tests for *Task D* were all nonsignificant except for two variables: search speed/course length (i.e., search time) and level of effort expended during search. Factor analyses of the *Task B* and *Task E* individual difference and detection proficiency data showed that search time and the effort ratings consistently loaded on the same factor as performance measures of detection proficiency. Further, these analyses indicated that conventional paper-and-pencil tests, at least to the extent these tests were included in the *Task B* and *Task E* research, did not measure detection performance. Finally, in *Task F*, the evaluator effort ratings were found to be significantly correlated with vehicular detection performance.

In addition, the results of the multiple regression analysis performed in *Task E* indicated that the *Task B* predictor battery was not adequate for predicting detection performance in the built-up area test environment. That is, this predictor battery did not cross-validate from a field detection to a built-up area detection situation.

Several inferences can be drawn from these analyses. First, it seems unlikely that field detection performance will be measured through the use of paper-and-pencil tests. The skills involved in taking such tests appear simply to lie on a different dimension from that on which lie the skills involved in detection of mines and boobytraps.

On the other hand, there is a consistent and large correlation between the time spent in the detection task and the number of devices found. There is also very substantial correlation between detection success and rated effort. While the time expended during search and the amount of effort the subject seems to be putting into it are also highly correlated, they are not sufficiently correlated to permit the judgment that time and effort are really the same underlying variable. To some extent, the rating of effort apparently measures something different from the measure of time alone. The fact that these two measures predict detection performance so well, and load on the detection factor so highly, suggests the possibility that it might be necessary to construct an entirely different kind of model to account for mine and boobytrap detection performance.

It seems as though this different model needs to be probabilistic, and perhaps needs to build on the research derived from studies of vigilance phenomena and information rate processing models, rather than the more deterministic models that have been used thus far. In a recently reported study, Teichner and Krebs[1] analyze research findings from a number of investigators, and develop an information rate processing model to deal with visual search for simple targets. While some of the conditions characterizing the studies reviewed by Teichner and Krebs are quite different from those characterizing field detection of mine and boobytraps, there also are some surprising similarities.

[1] Teichner, Warren H. and Krebs, Marjorie J. "Visual Search for Simple Targets," *Psychological Bulletin*, vol 81, no 1, 1974, pp. 15-28.

Perhaps the most basic deduction reached by Teichner and Krebs is that there is a limiting rate at which information can be centrally processed by humans. While their data do not address individual differences, it does appear that limiting rates can be established on a group basis. Time required to detection on a group basis, therefore, becomes a probabilistic function of the number of stimulus elements to be detected, in relation to the total number of stimulus elements in the array.

Clearly, field detection of mines and boobytraps is quite a different matter from the well-controlled kind of studies that can be conducted in laboratories. The detection tasks posed by paper-and-pencil tests, such as the Embedded Figures Test and the Information Extraction Test, also pose a clear-cut, well-controlled kind of rate situation. By contrast, the natural setting in which mines and boobytraps are found is tremendously more cluttered with irrelevant stimuli, and the variability of background clutter is extremely high. Further, tactics for concealment range from utilizing background clutter to attempts at causing devices to blend into a homogeneous field.

While the kinds of studies used by Teichner and Krebs for their analysis thus differ substantially from the kind of task posed in field detection of mines and boobytraps, enough similarity remains to suggest that an information rate processing model might be more suitable for conceptualizing mine and boobytrap detection as well. The influence of time in the present studies has been consistent and large. This suggests the possibility of a rate limiting variable. Further, the rating of effort by experimenters could easily be conceptualized as their impression of how close to his own rate the individual subject appears to be trying to operate in the experimental situation.

Finally, Teichner and Krebs found at least some tentative suggestions that "chunking" might be occurring with very high rates of information processing. That is, once a plateau appeared in the processing of individual bits of information, subsequent increases in processing rate, though tentative, suggested the possibility that the subjects might have begun processing combinations of stimulus elements rather than individual elements.

The focus of the IDENTIFY research has been on individual differences. It is possible from these tentative speculations to infer where the individual differences might arise. First, it is entirely possible that information processing rate limits are different from individual to individual. Second, it is possible that some individuals are willing to work harder—that is, to deal with information at rates closer to their own individual limits, and for longer periods of time—than are other individuals. These persons would be judged to have higher motivation, and would probably be those individuals rated to have exerted higher effort during field detection studies. Finally, it may be that "chunking" skills are a third source of individual differences. Since there is some evidence that chunking skills are learned, this area of individual differences might be the most useful to exploit when training individuals to be mine and boobytrap detectors.

Anecdotal evidence from studies of mine and boobytrap detection tends to give support to the inferences just discussed. Typically, especially with the detection settings used in the present studies, the detection task itself is not difficult, in the sense that some psychomotor tasks are difficult. Instead, the stimulus element that signifies the presence of the device generally is invisible to the searcher until it suddenly becomes visible. That is (and there is no attempt to be facetious), he does not see that stimulus element until he sees it, after which time he easily sees it at any time he wishes. Thus, seeing the stimulus element is not necessarily a difficult task, perhaps depending more on the persistence of the individual at examining the stimulus elements in his environment than on his ability to see them in and of themselves.

HUMAN FACTORS DATA ANALYSIS

False Detections

Both in the IDENTIFY research described in this report and in the *Task B* research, some false detections were produced by the soldiers. These represented only a small percentage of the total number of detections in each operational environment studied. A conclusion to be drawn is that subjects, in a test situation, apparently are not inclined to make a response unless they are reasonably certain "something" is there to be detected.

Foot-Mobile Detection in a Field Environment

In *Task D*, the study of the detection process in a field environment by foot-mobile subjects, begun in *Task B*, was continued. In contrast to the *Task B* results, detection rate was not related to devices' above-ground or below-ground location for the *Task D* mine and boobytrap course. Comparison with the *Task B* results showed that this was due to (a) above-ground devices in the present study having a lower detection rate, relative to the *Task B* above-ground devices, and (b) below-ground devices in the present study having a higher detection rate, relative to the below-ground devices in *Task B*. It was suggested that, because above-ground devices were made more difficult to detect for the present study, this resulted in the men orienting more toward the ground during their search. Clearly the detectability of above-ground and below-ground devices may be affected by changes in the difficulty of either type of device.

The average detection distance, however, was found to vary as a function of the device size. This was also true for the *Task B* research. This result suggests that a major key in device detection is size: Given that an individual is looking in the "right direction," larger devices will be detected at a greater distance than will small devices. Thus, one characteristic the optimal mine/boobytrap should possess is "smallness."

It was found that for the small, on-path devices, detectability decreased with increases in off-center distance. For those devices that did not intersect completely across the path of advance, activation rate decreased also. The implication of these findings is clear: Detection of small ground devices can be reduced by keeping them out of the path center, but at the expense of reducing their activation.

For devices located off the path, detection rate increased with increased off-center distance. This was apparently due to the fact that the farther devices were larger than the nearer devices. Thus, size appeared to be the controlling factor for this case. The result simply reinforces a prior statement: Larger devices are detected at longer distances and at higher rates than smaller devices.

Detection rate was also found to increase as the terrain vegetation increased. It was suggested that this result occurred because as the amount of vegetation increased, the soldiers became more cautious in their searching.

In addition, it was found that the average detection distance for above-ground devices appeared to decrease in terrain with vegetation, compared to terrain with little or some vegetation. It was suggested this was because long-distance discriminations are more difficult to make in complex terrains. The implication is clear: Placement of large devices should be in terrain with vegetation, where detection distance is minimized.

Finally, it was found that the grade of the detection course appeared to affect the detection rate. It was suggested that this was due to two factors: One was fatigue; the other was the fact that on a decline, an individual's eyes are farther from the ground than when he is on an incline or level grade. This suggests that when an individual is searching on a decline he should crouch toward the ground to minimize the eye-to-ground distance.

Analysis of detection clues during *Task D* showed that color and shape were important factors in determining the detection of devices. Analysis of errors of device placement indicated that inadequate camouflage was also important for the detection of devices. These results parallel those reported in the data reanalysis performed in *Task G*. This suggests that if devices are camouflaged so that color and shape are obscured, device detectability will be reduced.

Foot-Mobile Detection in a Built-Up Area Environment

In *Task E* the study of the detection process in a built-up area environment by foot-mobile subjects was initiated. Overall, the men were more likely to detect devices than to miss or activate them. The average detection rate per man was 70.2 percent. Further, if subjects did not detect a device, they were more likely to miss than to activate it. However, this does not present the whole picture. Upon inspection of the detection, miss, and activation rates of individual devices, it was found that devices could be divided into two classes: those detected or missed, but seldom activated (84.1%): and those detected or activated, but seldom or never missed (15.9%). Evaluation of the devices in each category indicated that Detected/Missed devices were generally emplaced off the soldier's direct line of advance. It would follow that these devices would be unlikely to be activated, assuming that care was taken not to disturb possible hiding areas during the search process. For devices in the Detected/Activated category, evaluation indicated these were generally emplaced across a soldier's path so that their activation was a very probable event if they were not detected and avoided.

Detection rate for each category of device appeared to depend upon different variables. For Detected/Missed devices, rate was associated with the type of location in which devices were placed, that is, whether they were hidden under (high rate) or inside (low rate) objects. For Detected/Activated devices, rate was associated with level of visibility.

For both types of devices, the primary detection clue was an exposed triggering device. This was also the primary clue at each detection rate (low, medium, and high). Taken together these results indicate that (a) detection of Detected/Missed devices was essentially based upon the subjects' orienting in the direction of and traveling to objects likely to hide a device, and discovering the device's presence through observation of an exposed triggering device; and (b) detection of Detected/Activated devices was based upon the subjects' noticing the exposed triggering device. In the latter case, orientation was probably not important, since these devices were placed along the soldiers' path.

It would be expected that for situations where the men had to orient toward and travel to devices, average detection distance would have little importance in the detection process. However, where visibility was a factor and orientation already essentially given, it would be expected that distance would be a factor. The data tend to support this conclusion. For Detected/Missed devices, average detection distance did not show any indication of being associated with average detection rate. For Detected/Activated devices, this trend was evident, although not statistically significant.

Four categories of search techniques were assessed during the criterion test. The best search technique was identified by looking at the average detection rate as a function of the individual techniques defining each category. It was determined that the most successful technique should consist of: (a) searching floor and furniture alternately; (b) searching all areas systematically; (c) searching on, in, and under furniture; and (d) using the sense of touch to supplement visual search.

Vehicular Detection in a Field Environment

In *Task F* the study of the detection process in a field environment by vehicular-mounted troops was initiated. The results of *Task F* indicated that it is possible to detect

hidden mines and boobytraps from a moving vehicle. However, the detection rate obtained under these conditions was found to be a joint function of the type of vehicle and the field environment in which the detection task was accomplished. It was found for a road environment that the detection rate was highest when the men traveled in a jeep, and lowest when they traveled in a tank. However, there was a reversal of this result when the task was accomplished in a cross-country environment. That is, detection performance from the tank was superior to jeep detection performance in the cross-country environment. In both of these environments, however, detection performance from a moving armored personnel carrier was essentially at the same level; that is, for this vehicle the detection rate was relatively unaffected by a change from a road to a cross-country environment.

These results suggest the following:

(1) When high vehicular detection rates are needed for a road situation, the detection task should be accomplished from a slow-moving jeep; when high detection rates are needed in a cross-country situation, the task should be accomplished from a slow-moving tank.

(2) When there is a vehicular detection requirement that will involve both road and cross-country travel, the armored personnel carrier should be used since detection rate was essentially the same in both of these environments for this vehicle.

As implied above, there was a significant difference among the detection rates for the three vehicles studied in the road environment; detection rate was highest from the jeep, next highest from the APC, and lowest from the tank. Additionally, on the road course, the detection rate was found to vary inversely with speed; that is, at a lower speed the average detection rate was higher than at a faster speed, for all vehicles studied. This finding indicates that for the best results vehicular detection should take place at low (5 mph or less) speeds.

It was also found that device detection rate varied as a function of device location and the type of vehicle from which subjects completed the detection task. For the jeep and APC conditions, detection performance was highest for devices in the center of the road, while for the tank condition it was highest for devices on the right-hand side of the road and lower for devices on the left or middle of the road. This result suggests that the type of vehicle from which subjects detected devices influenced where they looked for devices.

It was found that the detection rate for on-road and off-road devices did not differ significantly, but the average distance at detection for these two classes of devices did vary. Off-road devices were detected significantly farther away than on-road devices. This finding suggests that device visibility was a factor in the detection process on the road, since it was necessary for the men to get closer to the on-road devices than the off-road devices for detection to occur at essentially the same level.

On Course No. 2 and Course No. 3 (the cross-country environments), detection performance was best from the tank; detection performance from the APC was second best, and detection performance from the jeep was last. Soldiers on these courses traveled through the center of the courses at speeds of less than 5 mph. The detection rate differed for devices on the left and right halves of the course. For Course No. 2 (hasty minefield), detection rate was highest for devices on the left half of the course for detection from APC and tank, and highest on the right half for detection from the jeep. On Course No. 3 (deliberate minefield), detection rate was generally higher on the right side of the course for both large and small mines. These findings indicate that device location is an important factor influencing the detection process in a cross-country situation, just as it was in the road situation.

On both cross-country courses, it was found that the observer-to-device range significantly affected detection performance in an inverse manner. That is, the detection

rate tended to decrease as the observer-to-device range increased. This is an expected result. For example, Caviness and Maxey[1] found a similar result for human targets detected by stationary human observers. As target-observer distance increased, detection rate decreased for these targets. This result is simply a reflection of the fact that for objects of the same size, as the physical distance between the object and observer is increased, the object has an optically smaller size and is less visible, and hence less detectable.

On Course No. 3, it was found that large mines were detected at a higher rate than small mines. This result reflects that for similar observer-to-target ranges, larger objects are more visible than smaller objects, and hence are more detectable.

In a plowed strip containing five buried mines on Course No. 3, most of the subjects noticed one or more mines. However, the average detection rate was only 60 percent. This finding indicates that detection of a plowed strip is not very difficult but that detection of all mines in the strip will average less than 100 percent.

The men indicated when they detected the forward edge of the minefields on Courses No. 2 and 3. It was found that the forward edge of the hasty minefield was more difficult to detect than the forward edge of the deliberate minefield. This result suggests that the forward edge of the hasty minefield was less visible than the forward edge of the deliberate minefield. That this was probably the case is reflected in the fact that the average distance from the forward edge of the minefield at detection was less for the hasty minefield than the deliberate minefield for the tank and jeep. For the APC, the average distance from the forward edge at detection was essentially the same.

The importance of the differential difficulty of the detection of the forward edge of the minefield was that, for the more difficult situation (hasty minefield), observers in all three types of vehicles detected the forward edge at essentially the same point, while for the less difficult situation (deliberate minefield) men in the tank and jeep detected it farther away than did the men in the APC. These results suggest that for situations where a minefield's forward edge is either relatively invisible or ill-defined, detection of this forward edge will occur close to the edge and at a low rate. For situations where the forward edge is relatively visible or well defined, detection may occur far away from the edge and at a high rate.

On both the cross-country courses, subjects indicated when they felt they were out of the minefield. For both courses, they generally indicated they were out of the minefield somewhat after they had actually left. This result suggests that detecting the end of a minefield prior to exiting is a much more difficult task than detecting the beginning of a minefield prior to entering it.

EVALUATION OF THE FILM SIMULATOR

The results of the *Task D* study replicate those of Bucklin and Wilson to the extent that statistically significant correlations were obtained between scores achieved on a test of detection proficiency involving a prototype film simulator, and scores achieved on both surface-laid munitions and mine and boobytrap test courses. However, the magnitudes of the obtained correlations were less than (though not significantly different from) the magnitude reported by Bucklin and Wilson for a similar film/field correlation. It was mentioned in the results that several factors may have contributed to the lower correlations found in the *Task D* study: differences in subject population, differences in the

[1] Caviness, James A., Maxey, Jeffery L., and McPherson, James H. *Target Detection and Range Estimation*, HumRRO Technical Report 72-34, November 1972

films employed during testing, and differences in the field test courses that were evaluated.

Typically, the Picatinny Arsenal has employed relatively well educated troops in their detection studies. In Bucklin and Wilson's film/field study, the troops were all college graduates with engineering backgrounds. None had had any prior experience at a detection task, except what they may have completed in Basic Combat Training (BCT). In contrast, HumRRO studies have employed less well educated troops (usually an average of 10 years of education) who have little or no technical training. None of these men had any prior experience at a detection task either, except what they received in BCT/AIT. Thus, the basic differences in the two groups of subjects were the educational and technical background of the troop populations sampled. It may be that better-educated personnel are able to profit more from a film training experience than less well-educated personnel. If so, this could partially explain why the Picatinny Arsenal study obtained a higher-magnitude correlation than the *Task D* study.

However, the differences in the films and field courses evaluated may have been the biggest factor that impacted on the magnitude of the correlations obtained in the Picatinny Arsenal and the *Task D* study. In the Picatinny study a single film and field course was evaluated. There was a variety of the same items for detection on the film and field course: long and short cylinders either olive drab in color or covered with leaves, grass, or peat moss. For both sets of detection scores, the distributions were roughly symmetrical. Thus, there was a variety of items available for detection and no apparent restriction of range for either test score distribution. Therefore, conditions were optimal for correlating film and field test scores. Under these conditions, finding a correlation of moderate magnitude between a film version of a field course and the field course itself would not be unexpected.

On the other hand, the conditions for the development of moderate-magnitude correlations between film and field performance were not that optimal for the *Task D* study. The film evaluated presented two kinds of objects for detection: differently colored discs (silver and olive drab) and long, olive drab cylinders. The distribution of the scores from the film test was relatively symmetrical. The surface-laid munitions course evaluated presented the same items as did the film. However, the distribution of scores from this test was negatively skewed; that is, it tended to be very easy to complete. Thus, for the film/field correlation in this case, the conditions were not maximized for the development of a moderate-magnitude correlation. This implies that the true value of the significant correlation obtained was attenuated.

Perhaps, had the field test scores for the surface-laid munitions course been more symmetrical in distribution, a higher-magnitude correlation would have been obtained. This finding suggests that for future work in this area, the field test corresponding to the film test be sufficiently difficult to provide a symmetrical distribution of test scores. This was not possible in the *Task D* study since the film course was developed from a pre-existing film course.

The mine and boobytrap course evaluated presented different and more varied items than the film evaluated. Scores from this test had a relatively symmetrical distribution, so statistical conditions were adequate for the development of moderate magnitude correlations. The failure to find a moderate or high correlation between film and field performance in this case, then, probably reflected differences in test items between the surface-laid munitions and the mine and boobytrap courses. If this is true, it would be expected that scores from a film version of a mine and boobytrap course would have a moderate to high correlation with scores from the actual field version.

The film simulator evaluated in the *Task D* study appeared to have limited value as a training device. Soldiers who completed the field test after viewing the film did no better on the field test than those who did not complete the film test prior to their field

testing. The film presented an image that lacked depth, so it did not accurately simulate the field detection situation. Also, some segments of the film lacked the optical clarity necessary for detection tasks of this type. It is believed that this factor contributed to the film test being more difficult ($\overline{X}$ = 44.5%) than the field test for the surface-laid munitions course ($\overline{X}$ = 92.1%).

However, it is believed that some type of visual presentation (e.g., film or slide picture procedure) could be developed that would correct these defects. A stereoscopic color slide presentation, for example, would provide an image with depth. Three-D films, designed to be viewed with stereo glasses, might also provide an image with depth. Finally, with the current state of the art in holography, it is possible to project three-dimensioned images. With the proper camera equipment and technique, clear and naturally illuminated images can be produced. Thus, it appears that this is an area where additional research could produce a valuable aid in the training of, and possibly even the selection of, mine and boobytrap detectors.

TASK G DATA REANALYSIS

The reliability analyses of the *Task B* data suggested that individual device detection scores from individual lanes were not sufficiently reliable for use on an individual basis. That is, whether an individual did or did not discover a given device on any given lane appeared to be substantially influenced by chance factors. Further, the sums of his individual device detections *per lane* seemed also to be excessively determined by chance for individual use. However, the total of the device detections for even lanes and the total for odd lanes, when added together, give a sum which meets reliability criteria that are conventional for psychological test construction. Thus, it seems reasonable to conclude on the basis of the analyses performed that the total detection scores reported in the *Task B* study were sufficiently trustworthy as a criterion that they might be used with confidence as a basis for validating predictors.

It seems reasonable to infer from these findings that quality of detection performance is indeed a consistent attribute of the individual. There was some evidence, mentioned in the results section of Chapter 4, that the aptitudes and abilities underlying detection of above-surface devices differ from those required to detect subsurface devices. Even so, detection skill was sufficiently consistent that high scores on one type of device tended to be associated with high scores for other types of devices as well. This tendency was not nearly as strong as was the tendency for detecting devices of a similar type—that is, all subsurface or all above-surface—but it was present, nonetheless.

Two sets of implications emerge. First, analysis of the reliabilities suggests that the *Task B* Course I was probably satisfactory for individual use where total scores were used as the criterion of performance. Further, the construct validity studies, especially the factor analysis studies and the correlations of total scores from odd to even lanes, suggested that adjacent lanes did, in fact, pose a relatively similar task to subjects. The inference is that all lanes did, since all lanes were constructed using the same rigorous guidelines.

Second, for possible future studies wherein it might be desirable to study individual performance by type of device detected, it probably will be necessary to increase the number of exposures each individual has to each individual device type.

The reliabilities found in the *Task G* study acted very much like item reliabilities on a paper-and-pencil test. The reliability of a single item on any given test is relatively low. It is subject to both sampling and measurement errors. That is, the specific items on a test are sampled from a population of items from the entire domain which the test purports to measure. If a subject can respond correctly to 70 percent of the items in that

domain, the odds are seven to three that he will respond correctly to any randomly selected item from the population of items. If by chance a given item has been selected from the 30 percent to which he cannot answer correctly, he will respond correctly to that item only by chance. Even if the item has been selected from that part of the domain which the subject knows, he may respond incorrectly because he does not understand the item. This would be a type of measurement error.

It is probable that device location in the mine and boobytrap lanes of the *Task B* study carried error components analogous to those two described above. In conventional tests, higher reliabilities are achieved through the inclusion of more items. The analysis of reliabilities from the *Task B* study suggests that reliability increases with an increasing number of observations in the mine and boobytrap detection course, in a quite similar way. In summary then, it appears that the *Task B* total score reliabilities were quite satisfactory, meeting the conventional criteria for test reliability. Further, it appears the reliabilities can be modified upward if desired by increasing the number of observations, if high reliabilities are necessary.

Chapter 6

CONCLUSIONS

Based on the results of analyses involving predictor and criterion data for both field and built-up area detection situations, it was concluded that the detection of mines and boobytraps depends on underlying skills and processes that simply are not measured by conventional paper-and-pencil tests, at least not by those employed in the IDENTIFY research. It was found that the predictors which consistently correlated with detection performance were those obtained from within the situation itself, that is, time expended in search and apparent effort expended. These findings suggested that it may be necessary to account for mine and boobytrap detection performance by a different model than has been used thus far. In particular, an information rate processing model with a motivational component was suggested.

Data analyses addressing the human factors involved in the detection of devices in a variety of operational situations were also conducted. Over all situations, false detections continued to represent a very small percentage of the total detections produced by the subjects.

For *Task D*, which studied the detection of mines and boobytraps by foot-mobile soldiers in a field environment, the following human factors information was developed:

(1) In contrast to the *Task B* results, detection rate was not related to devices' location above ground or below ground for the *Task D* mine and boobytrap course (analysis suggested this was due to a change in the difficulty level of above-ground devices from *Task B* to *Task D*). However, average detection distance varied as a function of device size.

(2) Device detectability was related to the off-center distances for the small, on-path devices, as well as for the large, off-path devices.

(3) Detection rate varied as a function of terrain vegetation.

(4) The grade of the detection course appeared to affect the detection rate.

(5) Color and shape were important clues in determining the detection of devices.

(6) Analysis of errors of placement indicated that inadequate camouflage was important for detection of devices.

(7) With reference to search procedures employed by subjects, an area search/footfall combination achieved the best results.

For *Task E*, which dealt with the detection of mines and boobytraps by foot-mobile soldiers in a built-up area environment, the following human factors information was identified:

(1) Devices employed during the proficiency testing could be classified as:

(a) Those detected or missed, but seldom or never activated.

(b) Those detected or activated, but seldom or never missed.

(2) Detection rate for each category of devices appeared to depend on different variables. For Detected/Missed devices, rate was associated with the location of the devices, while for Detected/Activated devices, rate was associated with level of visibility.

(3) A search technique for built-up area detection was identified from the techniques employed by the subjects. This consisted of:
  (a) Searching floor and furniture alternately.
  (b) Searching all areas systematically.
  (c) Searching on, in, and under furniture.
  (d) Using the sense of touch to supplement visual search.

For *Task F*, which dealt with the detection of mines and boobytraps by vehicular-mounted troops in a field environment, the following human factors information was identified:

(1) The detection rates obtained by mounted troops in field areas depend jointly upon the type of vehicle from which detection occurs and the type of environment through which the vehicle is traveling.
(2) The detection rates obtained from a moving vehicle will vary inversely with the speed of the vehicle.
(3) The type of vehicle from which detection occurs may interact with the location of the devices emplaced in the detection environment to influence the detection rate.
(4) The detection rate is also a function of the observer-to-device range for devices of a given size.
(5) For devices at the same observer-to-device range, the detection rate will be directly related to device size.
(6) The detection of the forward edge of a minefield is directly related to its visibility, with more visible forward edges being detected at greater ranges than less visible forward edges.
(7) The detection of the end of a minefield prior to exiting it is more difficult than the detection of the forward edge of a minefield prior to entering it.

In the evaluation of a film simulator during *Task D*, the correlations between film and mine and boobytrap test proficiency, as well as between film and surface-laid munitions test proficiency, were statistically significant ($r = .33$ and .31, respectively) although of low magnitude. These results replicated a previous finding of researchers at the Picatinny Arsenal, only to the extent that statistically significant correlations were found between film and field detection performance. The correlation reported by the Picatinny study was higher than those found in the present research, but statistical tests showed that there was no significant difference between them. It was concluded that the true value of the correlation between film and field detection performance was probably between .31 and .60.

Further analysis of reliabilities from Course I of the *Task B* study indicated that they were, in general, satisfactorily high. If attention had been focused on individual device detection scores by individual subjects, an increased number of observations would have been necessary to achieve a satisfactory level of reliability in those scores. Thus, where total detection scores are used as a criterion, the procedures used in the *Task B* study were quite satisfactory. For studies focusing on detection by individual device, more observations would be needed and it might be desirable for all subjects to traverse the same detection lanes.

Appendix A

TEST MATERIALS

The identification of individual differences was explored in the various IDENTIFY studies through use of some or all of the tests described.

(1) IDENTIFY Information Form. This HumRRO form was designed to collect three types of information: (a) write-ins (name, Social Security account number, and unit); (b) educational completions (number of years of civilian education completed and means by which a high school diploma was earned); (c) responses to two questionnaires (the IDENTIFY Opinion Questionnaire and the Activities Inventory - Part I).

(2) IDENTIFY Opinion Questionnaire (Rokeach's Dogmatism Scale). This is a 40-item scale designed to measure the extent to which an individual has a dogmatic (closed) belief system. It has been shown to have a test-retest reliability of .71 (5-6 months) and a split-half reliability of .78 (corrected). Scores on the scale are related to the difficulty an individual has in solving a problem after established belief systems are overcome.[1] Examinees indicate how much they agree or disagree with each item using a five-point Likert Scale. Their score is the average of their responses.

(3) Activities Inventory - Part I. This inventory consists of a list of 30 activities frequently engaged in by young males during their school-age years. To complete the inventory, an examinee indicates the frequency (never, few times, often, very often) he has engaged in each activity. The average of these frequencies over the 30 activities provides an index of the examinee's activities participation.

(4) Task Orientation Inventory. This 22-item scale is designed to measure the extent to which an individual is concerned with completing an assignment, solving a problem, working persistently, and doing the best possible job. The items were extracted from a 40-item scale[2] on the basis of results of an item analysis of data collected during a pilot administration of the larger inventory. The items retained were those which discriminated most between high and low scores for the complete inventory. Examinees indicate how much they agree or disagree with each item, using a five-point Likert scale. Their score is the average of their responses.

(5) AM Scale. This is a 9-item scale designed to measure an individual's generalized need to achieve when performing his work. Work in this context was taken to mean those activities performed to earn a living. The items were based on a set developed to study students' achievement motivation in a school situation.[3] The student-oriented items were rewritten to reflect a job or work orientation. Examinees indicate how much each item is true for them, using a five-point scale. Their score is the average of their responses.

(6) Hand Skills Test. This test was designed to measure an individual's motivation to persist beyond minimum standards on a tiring task. It consists of sequentially numbered

[1] Rokeach, M. *The Open and Closed Mind*, Basic Books, New York, 1960.

[2] Ray, J.J. "Task Orientation and Interaction Orientation Scales," *Personnel Psychology*, vol. 26, 1973, pp. 61-73.

[3] Myers, A.E. "Risk Taking and Academic Success and Their Relation to an Objective Measure of Achievement Motivation," *Educational and Psychological Measurement*, vol 25, 1965, pp. 355-363.

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boxes in which examinees pencil five tally marks. It has a one-minute practice session and three subsequent parts of four minutes each. The test promotes hand and arm fatigue and is presented to examinees as a measure of hand and finger dexterity. A "passing score" is announced prior to each of the four-minute parts (pretesting has established that this score can be reached by all examinees in the time allowed).

The test is designed to discriminate between those who stop or slow down after the passing score is reached and those who continue to strive. The score is the number completed in Part Three minus the number completed in the practice session.

(7) Hidden Figures Test (Cf-1). This is a two-part test of an individual's ability to determine which of five achromatic simple figures can be located in achromatic complex patterns. Each part of the test has 16 complex pattern problems for the examinee to solve. Examinees have 10 minutes to complete each part of the test. The score on the test is the total number of simple figures located in the 20-minute testing period.

(8) Embedded Figures Test (ETS Group Version) This 12-item test is designed to measure the facility with which an individual can locate simple figures hidden in complex patterns. The 12 items comprising the test were selected by Jackson, Messick, and Myers[1] from the 24 items comprising the Witkin Embedded Figures Test.[2] The test is group-administered and requires examinees to remember a previously shown figure when a particular complex figure is being scanned. This is in contrast to the Hidden Figures Test which keeps the simple figures on display at all times. In addition, 11 of the 12 complex figures are colored. All simple figures are achromatic. The score for the test is the number of correct identifications made in ten (10) minutes.

(9) Rod and Frame Test.[3] This is a performance test designed to measure an individual's ability to adjust a lighted rod to an upright position without external visual clues. The examinee's task is to adjust the rod to the true vertical with his body upright and the frame tilted at various angles off the vertical. Eight different combinations of frame position, rod position, and rod tilt for each direction of frame tilt constitute the test trials for the examinees.

The examinees are brought into the test room with their eyes closed, and they are seated. The experimenter sets the rod and frame positions for the examinees; then they are told to open their eyes for the first trial. As necessary, the experimenter makes adjustments in the rod's position according to instructions from examinees. These patterns—the examinees closing their eyes and the experimenter changing the rod and frame positions—continue until each examinee has completed eight trials. The score for the test is the sum of the deviations from the vertical.

(10) Visual Acuity Test. This performance test requires the examinee to indicate the direction (left, right, up, down) that upper case E's (subtending various visual angles) are pointing on a standardized eye chart. E's appearing on the same line subtend the same visual angle. From the top to the bottom of the chart the size of this visual angle decreases from 10 to 0.5 minutes of an arc. The examinee stands 20 feet from the chart, which has standard illumination. To test monocular acuity, examinees keep both eyes open while covering the eye not being tested with a piece of cardboard. For both

[1] Jackson, D., Messick, S., and Myers, C. "Evaluation of Group and Individual Forms of Embedded Figures Measures of Field Independence," *Educational and Psychological Measurement*, vol 24, 1964, pp. 177-192.

[2] Witkin, H.A. "Individual Differences in Ease of Perception of Embedded Figures," *Journal of Personality*, vol. 19, 1950, pp. 1-15.

[3] Witkin, H.A. and Asch, S.E. "Studies in Space Orientation. IV. Further Experiments on Perception of the Upright With Displaced Visual Fields," *Journal of Experimental Psychology*, vol. 38, 1948, pp. 762-782.

monocular and binocular testing, the examinees read each line of the chart starting at the top. The number of correct answers for each line is recorded by the examiner. In general, the more rows an examinee reads correctly, the better his visual acuity. Acuity disparity is then computed by taking the absolute difference of the measured acuity for each eye.

(11) Army Color Perception Test. This standard performance test is designed to screen for red-green color deficiency. It consists of one demonstration plate and 14 test plates, each composed of colored dots which form a number embedded within a circular background. The dots composing the number are a different color from those composing the background, but the colors are such that an examinee with a red-green color deficiency cannot distinguish the number from the background accurately. The score for this test is the number of test plates on which the number is correctly identified.

(12) GT Test Score. This is a score derived from the Army Classification Test Battery Verbal (VE) and Arithmetic (AR) test scores. This test score serves the function of determining which soldiers are qualified to take additional career important tests such as the Officer Candidate Test and the Flight Aptitude Selection Test. It is generally accepted that this score is a measure of general aptitude or ability.